
# EFFECT OF STARVATION WITH AND WITHOUT DESICCATION UPON WEIGHT, WATER CONTENT OF INSTARS AND SEXUAL BEHAVIOUR OF ADULTS OF GRYLLODES SIGILLATUS WALKER

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PARENTS

Effect of starvation with and without desiccation upon weight, water content of instars and sexual behaviour of adults of *Gryllodes sigillatus* Walker.

# A C K N O W L E D G E M E N T S

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ABDUL RAUF

# C O N T E N T S

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# CHAPTER - I

## INTRODUCTION

# INTRODUCTION

Crickets are the biggest household menace with an instinct of malevolence toward practically every conceivable object. Its cosmopolitan distribution with an utter disregard to the weather conditions makes it a potent pest of humankind and an object of hatred. Ideally in the house, it finds a cover under or behind anything that is infrequently disturbed, like the wall papers, cupboards, crevices, fabrics, garbage and even waste papers. Starchy food is palatable to these insects. It has a great biochemical reserve upon which it draws energy for the continuation of life processes at the time of food shortage. And it was this inherent forte in this species that stimulated the present research work. Though other aspects pertaining to behaviour and neural physiology of crickets have been thoroughly investigated and reported, yet practically no work has been done on the effects of starvation. In the present work on *Gryllodes sigillatus* Walker emphasis is laid on the effects of starvation with and without desiccation in relation to the weight and water content of the body. The study was conducted on all nymphal instars.

Since starvation promotes physiological changes which in turn affect the sexual behaviour, it was considered feasible to study the sexual behaviour of starving adults. Attention has also been focussed on its sound production which, as some researchers had reported in the past, play a dominant role in the transmission of sexual impulse to attract the sexually receptive females. Modern techniques of physics were employed particularly in the analysis of song and its parameters.

Since no work of this type has been done on Gryllodes sigillatus Walker, it has been selected for experimental purpose.

# CHAPTER - II

## REVIEW OF LITERATURE

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As far as the effects of starvation with or without desiccation is concerned, a lot of work has been done on Acridids but very little is known about the family Gryllidae. Starvation inhibits the moulting cycles in Locusta migratoria and blockage of normal development takes place as it checks the metabolic processes (Rinterknecht et al. 1972). In migratory locusts, the ecdysis is accelerated by starvation (Hill and Goldsworthy, 1970). Morril and Greene (1973) studied the effects of starvation in Spodoptera frugiperda and found that the newly hatched generally survived starvation period of 20-35 hours which allow them to select the feeding site. First instar hoppers of Aiolopus thalassinus (Ibrahim, 1973) are more susceptible to starvation than the older instars in which the resistance increases with age. Adult females show more resistance than the males. King and Hopkins (1963) showed that the life of virgin or mated female of Nasonia vitripennis is greater than that of males under similar conditions of starvation. During starvation of migratory locusts, fat body glycogen is utilized before fat body lipids as an energy source (Hill and Goldsworthy, 1970). Starvation studies in Gryllus campestris by using 2- dimensional paper chromatography have been done by Veselovsky et.al. (1971) for quantitative measurement of different aminoacids. Physiology of starvation has been extensively studied by Baud (1973) in B.mori. He did the biochemical analysis during starvation in the caterpillars of

Bombyx mori L. and found the existence of biochemically speaking two phases during absolute starvation in the caterpillars of Bombyx mori L. In the first phase a state of equilibrium is set up between the degeneration and the recovery. In the second phase irreversibility occurs which is followed by death. But being a complex phenomenon it cannot be ascribed accurately to a definite metabolic disequilibrium. He further investigated that the accumulation of food reserves in the earlier instars which enables adaptation in the larvae of B. mori L. to starvation. In these larvae lipids and glycogen are largely consumed but the water content in the tissue critically increases as the duration of the starvation is prolonged. The proteins are consumed in a very little quantity. While analysing the weight and the biochemical and secretory changes in the fourth and fifth instars subjected to total starvation, he found that the water consumption is constant in the first four days of starvation. About 83% sugars are utilized within the first two days. The glycogen content falls by >70% on the first day and becomes< 2% on the third and fourth day. About 86.5% lipids and 15% nitrogen are consumed in 4 days. Rastogi and Lohia (1972) conducted histochemical studies in Periplaneta americana and found that RNA and DNA content increases in the midgut during the starvation. The proteins which are distributed throughout the cytoplasm become diffused

during starvation. In desert locust, the starvation causes the reduction of the potassium, calcium and magnesium ions in the nerve tissue while the sodium ion is increased in the nerve tissue (Banerjee et.al. 1977). Aziz (1961) studied the relationship between starvation and activities of first instar hoppers of Schistocerca gregaria (Forskal) and found starved hoppers to discriminate the difference between the low and the high humidities. These hoppers avoid low humidities below 70% R.H. and high humidities above 70% R.H. but the hoppers cannot discriminate fully between the relative humidities 50% and 60%, and 60% and 70% as the time spent in both halves of the alternative chamber is not well marked. This is due to the restlessness (more activeness) of the hoppers during starvation. Starvation upto relative humidities 70% and 80% causes gradual increase in the activities i.e., time spent 'active', walking speed, hopping and turning. Adverse responses have been observed beyond 70% and 80% R.H. as the activities of the hoppers decrease , becoming more marked at 90% and 100% relative humidities. Aziz (1957,1960) studied the effects of starvation and preconditioning on the loss in weight and water content of the fourth-instar hoppers of Schistocerca gregaria Forsk. He preconditioned the newly moulted fourth-instar hoppers of Schistocerca gregaria Forsk. and fed for two days at 28°C and 77% R.H. He took out 20 hoppers after three days of preconditioning and divided them into two groups. After recording the

weight of each hopper, one set of hoppers was starved at low (30%) R.H. and the other at high (95%) R.H. After starvation of 32 hrs. weight of each hopper was recorded again and the loss of weight was calculated. To find out the water content left in the starved hoppers at low and high R.H. each hopper was placed in the oven at 120°C for 24 hrs. weight was recorded and then the water content was calculated. He found that the loss in weight at low (30%) R.H. is greater than the hoppers starved at high humidity (95%) R.H. but the water content in the two groups of hopper is the same. Aziz (1973) also studied the relation between starvation and activities of the fourth-instar hoppers of Schistocerca gregaria Forskal with or without desiccation. The starved hoppers can discriminate between low and high humidities. However, this discrimination is not well marked due to the restless condition of the starved hoppers. The time spent 'active' and speed of walking are affected by starvation while hops and turnings are not affected by starvation. In Spodoptera frugiperda (Morrill and Greene, 1973) starvation does not affect the percentage of survival, pupal weight and larval development time. Brannen (1975) observed that starvation causes cannibalism in the larvae of dermestid beetles. In Thermobia (Okasha, 1972) the percentage of water content is increased due to starvation. It was found that the $H_2O$ content in starved and desiccated beetles was above

the normal level. In dry air, the rate of water loss is independent of the 'water content'. Thermobia can take water from the saturated environment but severity of starvation before desiccation impairs the biological mechanism responsible for the uptake of water. Arbogast and Carthon (1972) found that Oryzaephilus surinamensis has a preferred R.H. range during starvation. Willis and Roth (1950) found that starvation affects the preference of humidities in flour beetle Tribolium castaneum. Mellanby (1934) found that the death of insects may result due to starvation at high temperatures which would have survived for longer duration at lower temperatures. Starving insects die earlier at higher temperatures than at low temperatures. Starvation affects the thermal death point of insects. Insects having small food reserves die at higher temperature from lack of food and water before they are affected by heat itself. Confined larvae of dermestid beetle can survive starvation because they can save themselves from the attack of cannibalistic individuals of their own species (Brannen, 1975).

Aziz(1960) has studied the effects of starvation and preconditioning on the water content and loss in weight of fourth-instar hoppers of desert locust, Schistocerca gregaria Forsk. Shelford (1914) gave the importance of evaporation. According to him, the environmental factors influence organisms

chiefly in one of the three ways: (a) by stimulating migratory animals and causing them to turn back; (b) by producing death, and (c) by modifying rate of metabolism, fecundity, length of life, size etc.. The experiments also showed that after the animals had been in dry air long enough to have a small amount of water withdrawn, they became more sensitive to the effects of evaporation. In general the reactions were similar for comparable rates of evaporation no matter whether the evaporation was due to dryness, temperature, or rate of flow of air. Furthermore, death was produced with the same symptoms regardless of cause of evaporation. The total effects of air, temperature, pressure, relative humidity and average wind velocity upon a free water surface is expressed by the amount of water evaporated. The same factors have been shown to determine the amount of evaporation from the bodies of the organisms. Water withdrawl influences irritability, activity and length of life history. The insect body is an armour of safety and a supporting structure of stability. But all the terrestrial animals have to solve the problem of desiccation and the adaptations associated with it. There are two main adaptations in the insect body: firstly the development of water proof external surface and secondly to conserve water and to minimise water loss through excretion (Wanton and

Ramsay, 1937). The effect of temperature, humidity and wind velocity upon the rate of evaporation of water from cockroach, Periplaneta americana, was studied by Ramsay (1935). The rate and the mechanism of the water loss by evaporation in insects has been studied by Uvarov (1931), Buxton (1932) and Mellanby (1935). Buxton (1930) suggested that mealworm desiccated for long period can make up some water by oxidation of larger amount of reserve food. Gunn (1933) observed that the rate of loss of weight is a satisfactory measure of the rate of evaporation of water from the animal. It was observed that at lower temperature the two larger species of cockroach lose water at about the same rate. The smallest Blattella germanica has a much higher rate of loss. Above 30°C, the rate of loss from the two smaller species increases very rapidly, while in Periplaneta americana the rate rises more uniformly (Gunn, 1935). Lindsay (1940) found silver fish, Ctenolepisma longicaudata, to absorb water from air near the point of saturation. Browning (1953) studied the influence of temperature and moisture on the uptake and loss of water in the eggs of Gryllus commodus Walker. Eggs placed in moist plaster take up water slowly at first then more rapidly untill they had reached their maximum water content. This duration of water uptake is dependent upon temperature. Aheran (1970) showed that the total water loss in tenebrionid beetles is composed of transpiratory losses from the cuticle and spiracles,

water associated with defaecation and the fluid droplets is released from the body for defensive purposes. Freshly killed specimens of tenebrionid beetles had higher transpiration rates over long and short exposures than did living animals of the same species. These results may show that active water retention ceases in dead animals. Physiological aspects of water balance in a number of terrestrial arthropods from a variety of habitats have been reviewed by Edney (1957,1967), Cloudsley-Thompson (1964), Bursell (1964) and Wigglesworth (1965). The apterygote Thermobia domestica takes up water from subsaturated atmosphere (Beament, Noble-Nesbitt and Watson, 1964; Noble-Nesbitt, 1969). The starvation with desiccation of this species for three days over dry $CaCl_2$ at 37°C results in a loss of some 20-25% of fresh body weight, mainly due to water loss. However, subsequent rehydration for one day of such treated insects, while still starved at the same temperature but exposed to 93% R.H., results in the attainment of approximately the predesiccation weight (Noble-Nesbitt, 1969; Okasha, 1971). The water content is reduced by desiccation, but following rehydration not only does it rise to its pre-desiccation level, but it exceeds the latter, primarily due to depletion of dry matter caused by starvation and secondarily due to water uptake from the atmosphere (Noble-Nesbitt, 1969; Okasha, 1971). Okasha (1971) suggested that water uptake in Thermobia does not take place to restore the 'normal' water content, but in order that

the insect can reach a particular volume and that the latter is characteristic of a physiological state of insects. Some insects fail to rehydrate, while in others both sexes differ in rehydration, sometimes one sex can rehydrate while the other sex cannot. The water uptake mechanism is primarily concerned with volume regulation (Okasha, 1971). Okasha (1972) observed that the percentage of water content can be increased by starvation. Both water content and rate of water loss remain constant throughout the moulting cycle. The rate of loss of water into dry air from starved insects is not dependent upon the water content of the insect, so the uptake mechanism is independent of the water content. Severe starvation before desiccation seems to impair or inhibit the uptake mechanism. This phenomenon is not the same in all arthropods. Edney (1957) established that a few arthropods take up water from subsaturated atmosphere. Noble-Nesbitt (1969) has given a list of arthropods which have such a faculty. Uptake mechanism is associated with integument (Edney, 1957). For cuticular permeability in Thermobia domestica, Beament (1964) suggested a model of water pump based essentially on the reorganization of lipid barrier in the epicuticle on the degree of hydration of the cuticular protein controlled by epidermis on the cuticular pore. Noble-Nesbitt (1970) showed that blockage of anus in Thermobia (which was desiccated) results in the

cessation of water uptake, therefore he concluded that rectum is the site of uptake. Okasha (1971) observed that the uptake mechanism is primarily associated with volume regulation and blockage of anus which arrests the uptake results in a nervous inhibition bringing such an effect. Despite these explanations the mechanism underlying the water uptake from the subsaturated atmosphere is not fully understood.

As regards sound production in insects Brooks (1881) was first to give a brief scientific account of the effects of temperature on singing of Oecanthus niveus. She stated that the temperature of the air can be estimated by counting the number of chirps of the cricket sound. This rule can be represented as: T=60+(N-72)/4 (T=temperature $^{o}$F and N = number of chirps per minute). Subsequent workers- Dolbear (1897); Bessy and Bessy (1898); Edes (1899); Shull (1907); Allard (1912 ,1917); Allard (1930 );Crozier (1924); Pierce (1948); Hallenbeck (1949); Allard (1957); and Walker (1957, 1962) modified this formula but Shull(1907) contended that while there is a general relationship between the temperature and rate of chirping, yet it is not possible to express it by any formula. Attention was later focussed on the mechanism of sound production and its associated behaviour in crickets. Many workers like Haskel (1964) and Alexander (1967) attempted to explain the mechanism of sound production.

The songs are species specific and the females of each species accurately recognize songs of males of their species. This very fact was utilized by many workers like Keeton (1967), Farler and Hamilton (1967) for species recognition with the help of the signals produced by the species. Walker (1957) proved it in Decanthinae and Paul (1967) in Achete finnutus. Similar works have been done by Hoy and Paul (1973), Shantiyer and Dubrovin (1974), Ulagaraj and Walker (1969, 1973) and Hill et.al.(1972). Mole crickets are attaracted towards the loudspeakers broadcasting natural or synthetic songs (Ulagaraj and Walker,1973) which can be used as means of control (Ulagaraj, 1975 , Ulagaraj and Walker 1973,1975). Other studies have been made on the sound production and migration in Gryllus campestris by Popov (1975). Reception of sound has genetic basic (Paul and Robert,1973). Phonetic classification was done by Vickery et.al(1970) and the relationship between song and evolution was established by Alexander (1975). In recent years the research has been done on the neurophysiological, anatomical and behavioural features of sound production. It is claimed to be produced according to circumstances (Rance,1977). Rapid antennation and the production of song have acoustic response to chemical stimuli from the surrounding (Paul, 1977). Rozhkova and Polishchuk (1976) localized the signal source in cricket's neurone and its directional selectivity. Majority of ensiferan Orthoptera regularly use sound during pair formation. Generally these

signals are produced when the two individuals are not physically in contact. The acoustic signals which convey pair forming message to the receiver are frequency, intensity, amplitude modulation, frequency modulation, transients, pulse rate and chirp rate (Alexander, 1967; Dumortier,1963). The role of pulse rate and chirp rate have been studied by Walker (1957). Later on it was reviewed by Alexander (1960) and Walker (1964). The calling song of field cricket is composed of stereotyped rhythmic pulse intervals. Walker (1960) taped the calling songs of Trochairis (Orthoptera: Gryllidae) and analysed the recorded sound with Kay Senograph. Similar studies were done by Madsen et.al. (1970) David (1976) and Paul (1976). Walker (1969) found that the chirps of Gryllodes consists of buzzy sound and has 10-14 pulses (corresponding to the wing closures). The increasing complexity of the song is described from the simple trill to the complex songs having modulation of pulse frequency and amplitude (Popov et.al.,1974) "Temporal and spectral characteristics of the calling sound, time patterns of amplitude modulation is a good diagnostic feature". (Popov et.al., 1974). Zhantiyev and Dubrovin(1974) found the calling songs of majority of Gryllinae and Nemobiinae consist of high frequency component (16-35 kHz) in addition to second and third harmonics. In Gryllinae the change from calling to courtship song is revealed by a considerable change

in both time as well as frequency of sound. Popov and Shuvalov (1974) investigated that the spectrum of male calling song in Gryllus campestris contains frequencies of 2-20 kHz. The spectrum has one major maximum near 4-5 kHz and two poorly expressed peaks in $\frac{1}{3}$ - octave bands having central frequencies of 8 and 12.5 kHz as the harmonics of calling song. Intensity of the calling song varies with distance from the calling male. The sound emission in male is directional. The neighbouring males orient themselves in such a way that their common emission of the song is most uniform in space. Rheinlaender et.al.(1976) electrophysiologically studied 2 ventral-cord neurons in the auditory system of G. bimaculatus. They found that 2 ventral cord neurons are highly evolved channels of the auditory pathway of gryllids. These transmit important features of the conspecific songs to various areas of the brain. Paton et.al. (1977) studied the large posterior tympanic membrane in Acheta domestica, Teleogryllus oceanicus and Gryllus pennsylvanicus. This membrane vibrates upto several hundred Angstroms in response to the sounds having same frequency and intensity as the calling song. The membrane vibrates in simple mode in response to tones from 4 to 20 kHz. Shuvalov and Popov (1973) studied the reaction of female of Gryllus to the sound. It depends on the rhythmic organisation of the song. The chirps determine the movement of female towards the sound-source. Frequencies of the pulse

repitition are responsible for species recognition. Donald and Paul (1973) while studying species specific song recognition in Teleogryllus commodus and T. oceanicus found that these species are species specific in song preference. Their hybrid prefers the call of a hybrid over either parental call. The ears of cricket Teleogryllus commodus are sharply tuned to the communicating signals of the species (Hill and Boyan, 1977). Paul (1976) found that in the absence of choice the females walked towards the loudspeaker playing a heterospecific song. In mixed groups interspecific courtship may occur due to mixed mating behaviour. These sympatric species ( Allonemobius fasciatus, A. allardi and A. tinnulus ) have reproductive isolation but it is not sufficient to prevent the interspecific mating. In Acheta the male jerks his body and produces 3 distinct courtship rhythms and a distinct pulse is produced at the end of the trill (Alexander, 1957). In advance courtship the male reverses his body backing towards the female's head. The male produces pulses at a rate of 5-6 per second. Then if the female shows responsiveness, she mounts herself at the back of the male. Alexander and Thomas (1959) observed in Nemobius tinnulus Fulton that the male approaches the female, delivering pulses at a rate of 2-3 per second in groups of 2-4. In the time space between each group he jerks the body. Then reverses his body, the back facing the female head. Afterwards copulation starts when the female mounts at the back of the male. In Nemobius fasciatus De Geer, first the male

produces 8-12 chirps per second, having 2-5 pulses per chirp. Then the chirps are produced in groups of 3-6 and the male jerks the body backward. In crickets (Alexander and Thomas, 1959) the female mounts the male in copulation and the male flattens his body against the ground, backing the female untill the physical contact is established. This final stage of physical contact depends upon the timely nature of the female. If the female is responsive she mounts over the male, otherwise withdraws the contact. Male stops courting if the withdrawal of the female is more pronounced and again starts the activities of the early courtship. If the female moves away then the male may produce defensive calls which are generally produced while encountering other male. Similar observation was made by Rence and Loher (1977) that the sexually receptive male responds with aggressive song to other male antennae and with a courtship song to the antennae of the female. Nielsen et.al. (1970) observed in Teleogryllus species that the male remains silent after copulation. Ahmad (1965) observed in Gryllodes sigillatus that the male produces chirping sound. The female rides over the male and this adjustment takes about 2-3 minutes. The male inserts it aedeagus in the genital opening of the female, below the ovipositor. The contact lasts for 2-5 minutes and the spermatophore, spermatic fluid with glandular secretion remains attached to the base of the ovipositor of the female. Spermatophore is sometimes eaten by female. While studying crowded behaviour of males when they

give mating calls collectively, Alexander (1975) argued that it is "forced by female sexual selection. In absence of paternal investment and where polygynous males are unable to increase their access to mates either by controlling areas where the females are dense (e.g., harems) or by controlling resources to which the females must come (e.g., oviposition sites), the criteria of mate choice exercised by females may focus on the acoustic display itself". In these conditions the female gets a 'selective advantage' as she selectively prefers a mate in the collective display of male singers. In the collective group of signallers she may prefer a superior male which can contribute certain superiorities to her male offspring. On the other hand males also have some advantage because in aggregation males attract a large number of females which is not possible if the males sing alone. Females also prefer to go to the aggregation of singers rather than as a lonely signaller. According to Alexander (1975) the acoustic displays of male katydids are likely to be important factors in the female's choice of the mate.

# CHAPTER - III

## MATERIAL AND METHOD

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The newly hatched first instar nymphs of *Gryllodes sigillatus* were taken and were placed separately in glass tubes, each measuring 10.7 cm. x 3.1 cm. The mouth of the glass tubes were covered by muslin cloth and tied with rubber bands. All the tubes were numbered. The weight of the glass tubes and that of the nymphs contained in them was recorded. The exact weight of the individual nymph was calculated by substracting the weight of the tube from the total weight of each tube with nymphs. These nymphs were divided into two groups. One group of first instar nymphs was placed in controlled chamber (Amtnco, American Instrument Company) at 30 $\pm 1^{\circ}C$ and 20 $\pm$ 5% R.H. to study the effects of starvation with desiccation. The second group of the first instar nymphs was placed in another controlled chamber (Orien, Orient Traders) at 30 $\pm 1^{\circ}C$ and 80 $\pm$ 5% R.H. to study the effect of starvation without desiccation. Temperature and humidity of the chambers was checked by centigrade thermometer and hair hygrometer (Barigo). In both the sets of experiments the weight of the nymphs was recorded after an interval of 24 hours till they died. Similar experiments were done for each instar (from first to sixteenth instars). The weight of the faecal matter of the individuals was also recorded daily. In 12th instar when sexes could be recognized due to the appearance of ovipositors in females and wing pads in males,

the weight of male and female nymphs during starvation with and without desiccation was also recorded as described above.

In order to determine the water content of the starved nymphs, with desiccation and without desiccation, each dead nymph was weighed and placed in numbered tubes. These tubes were placed in an oven at 110°C for 24 hours. These numbered tubes were taken out and kept in desiccators with KOH. The weight of each nymph was recorded. These were then placed in an oven for 2 hours and weights were again recorded. This procedure was continued till the weight was constant. The mean weight of water content was calculated for each of them. Thus the water content was recorded for each instar from first to sixteenth instars under starvation with desiccation as well as for instars under starvation without desiccation. Since a group of ten individuals was weighed at a time, a mean value was taken for each instar under both conditions (starvation with desiccation and starvation without desiccation). The weight of faecal matter was also recorded and the percentage of loss in weight due to faecal matter was calculated.

During the sexual behaviour the males of Gryllodes sigillatus produce a conspecific song to which the females

are attracted. This phenomenon, being an important part of sexual behaviour of this species, bio-acoustic studies were made to study the nature of song and to analyse its parameters in perspective of sexual behaviour under starvation with and without desiccation. The normal songs were recorded in a gallon jar as well as in cage measuring 30 cm. x 30 cm. x 30 cm in size. The floor of the cage was made of wood and the roof was made of wire gauze. The two sides of the cage facing each other were pannelled with glass while the other two sides were made of wood. One of the wooden side was provided with a circular window, measuring 15 cm in diameter, in the centre. A bag shaped cloth open at both ends was nailed to this circular opening. This was used for placing the adults inside and for taking them out. Recordings were done by National Cassette portable tape recorder at 30 $\pm$1 $^{o}$C. The songs of the starving individuals were recorded at intervals of 24 hours. As the individuals sing on their own so it was not possible to record it exactly at 24 hours interval. The recordings at constant temperature and humidity were done in controlled chambers. The tape recording microphone was placed inside the controlled chamber just above the gallon jar or the cage in which males were placed alongwith females for observation. The individuals were observed through the glass window of the cabinets. The tape recorder

was switched on as the male started stridulation and simultaneously the controlled chamber was switched off to avoid the noise of the machine. Courtship songs were recorded by placing males and females together in the cage. The observations were taken at 0 hour, 24 hour , 48 hour, 72 hour and 96 hour of starvation. The experiments on starvation with desiccation were done in controlled chamber at 30 ± 1°C and 20 ± 5% R.H. While the experiments on starvation without desiccation were done in controlled chamber at 30 ± 1°C and 80 ±5% R.H. The observations on sexual behaviour were recorded for 15-20 minutes in each case. The adults were starved in isolation due to their cannibalistic habits and the two sexes were brought together only during the period of observation. After the observations on sexual behaviour, the sexes were again separated and transferred to their respective gallon jars. To determine the chirp rate, the output of the tape recorder was converted into electrical signal by a microphone amplified by a pre-amplifier (CEERI make). Block diagram and photographic plate of the recording analysis system has been given in plate I and fig.1. The output of pre-amplifier was rectified by a diode and was filtered by a capacitor to reduce high frequency noise if any. The output waveform was recorded 1 inch/sec.on 15"x10" sized graph papers with the help of XY 2000 Recorder (Digital Electronics Limited, Houston Instrument). The chirp rate was calculated from the waveform. The length of the songs was directly determined by listening

Plate I. Photograph showing the recording and analysis system.

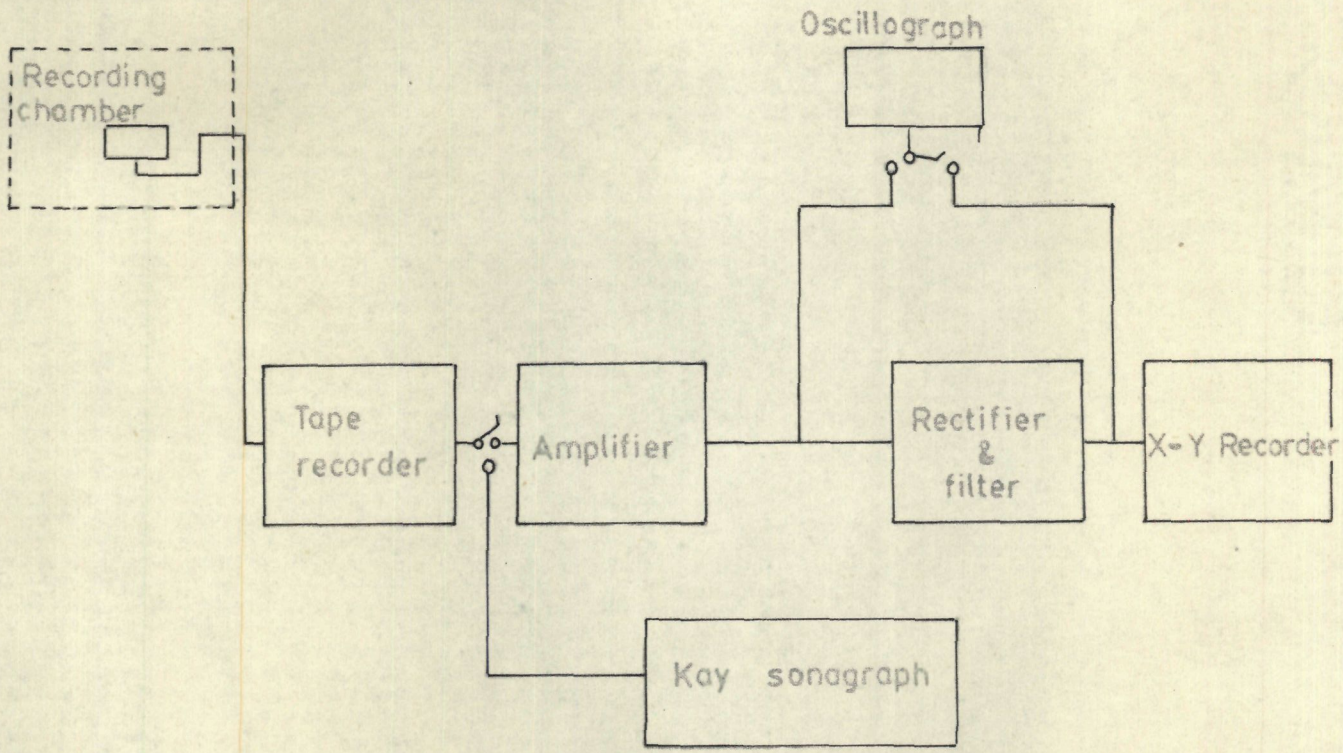


**Fig.1:** Block diagram of recording and analysis system

tape record output with the help of stop watch. To determine the variation in the chirp rate the song was recorded from National Cassette tape recorder to Sony TC 252 Stereo tape recorder with the help of Sony microphone. The recordings were done at a tape speed of 19.0 cm./sec. and the sound was reproduced at a tape speed of 4.75 cm./sec. The chirps were counted directly listening the tape record-output for each 10 sec. which in fact corresponds with the sound of 2.5 sec. of the actual. Audiospectrographs were made using a Kay Electrical Sonograph No. 7029 A. Frequency and other parameters of songs were analysed in audiospectrographs. Different portions of the songs were analysed by this method. In behaviour the preliminaries by males and females, their movements (active and passive) and time spent in copulation were noted.

CHAPTER - IV

# OBSERVATIONS

## O B S E R V A T I O N S

(1) Effect of starvation with desiccation upon the body weight of instars of *Gryllodes sigillatus*.

The results are summarised in Table 1 and Fig.2.

Due to starvation of the instars of *Gryllodes sigillatus* Walker, reduction in the body weight was observed in each instar separately from first to sixteenth under conditions of starvation with desiccation (Fig.2). Under such conditions the first, second, third and fourth instars exhibit a sharp and rapid decline in the body weight. These initial stages were seen acutely susceptible to the changed conditions of environment. A complex variability may be observed from first to sixteenth instar nymphs as far as the change in the body weight is concerned. In general, there is loss in the body weight with increasing age from first to sixteenth instar nymphs under this condition. The total loss in body weight is maximum in the first instar (83.34 ± 0.13 percent) while it is 23.91 ± 2.19 percent in the sixteenth instar females. In the tenth instar nymphs the loss in body weight is minimum (16.91 ± 1.62 percent). It is apparent from Table 1 that the total loss in body weight did not follow a simple pattern, but it varied very much from one instar to another. The difference between male and female sexes becomes apparent from twelfth instar onwards and there is a slight difference

Y weight per cent of the different nymphal instars of Cryllodes sigillatus under starvation with desiccation at 30 ± 1 °C and 20 ± per cent R.H.

| | WEIGHT % INSTARS* | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| II | III | IV | V | VI | VII | VIII | IX | X | XI | XII | | XIII | | XIV | XV | | XVI | |
| | | | | | | | | | | ♂ | ♀ | ♂ | ♀ | ♂ | ♀ | ♂ | ♀ | ♂ | ♀ |
| 0.00±0.01 | 100.00± 0.13 | 100.00± 0.39 | 100.00± 0.13 | 100.00± 0.32 | 100.00 ± 0.91 | 100.00 ± 0.91 | 100.00 ± 1.30 | 100.00 ± 1.80 | 100.00 ± 1.33 | 100.00±1.11 | 100.00± 1.07 | 100.00±1.03 | 100.00± 2.04 | 100.00 ± 3.18 | 100.00 ± 2.12 | 100.00 ± 2.13 | 100.00 ± 1.23 | 100.00 ± 1.23 | 100.00 ± 1.12 |
| 0.00±0.02 | 88.33± 0.12 | 88.88± 0.31 | 95.83± 0.13 | 98.88± 0.27 | 82.81 ± 0.42 | 84.89 ± 1.01 | 90.00 ± 1.71 | 93.12 ± 1.97 | 96.27 ± 1.15 | 99 .77±1.31 | 93.53± 1.87 | 96.60±1.34 | 90.48± 2.87 | 94.50 ± 3.12 | 96.20 ± 2.33 | 96.66 ± 2.83 | 94.61 ± 1.28 | 95.33 ± 2.31 | 94.92 ± 2.01 |
| 7.00±0.01 | 72.22± 0.14 | 77.77± 0.71 | 87.50± 0.17 | 82.22± 0.28 | 76.04 ± 0.81 | 70.83 ± 0.73 | 83.60 ± 1.18 | 85.95 ± 1.19 | 93.83 ± 1.54 | 96. 13±2.71 | 83.84± 2.03 | 87.42±1.11 | 74.14± 3.01 | 89.80 ± 2.84 | 93.54 ± 2.17 | 93.05 ± 2.72 | 94.04 ± 1.91 | 91.36 ± 3.42 | 91.93 ± 3.03 |
| 5.00±0.02 | 61.11± 0.13 | 70.37± 0.31 | 79.16± 0.12 | 68.88± 0.32 | 60.63 ± 0.77 | 62.60 ± 0.88 | 80.70 ± 1.53 | 85.95 ± 1.72 | 86.43 ± 1.63 | 93. 18±3.32 | 77.82± 2.10 | 81.83±1.23 | 71.65± 2.94 | 89.80 ± 3.91 | 88.35 ± 3.18 | 88.11 ± 2.12 | 93.53 ± 1.91 | 85.51 ± 4.03 | 87.74 ± 3.18 |
| | 33.33± 0.12 | 59.25± 0.26 | 70.83± 0.18 | 66.67± 0.21 | | 58.03 ± 1.12 | 74.78 ± 1.28 | 83.09 ± 1.31 | 81.63 ± 1.37 | 88. 63±2.42 | 64.82± 2.10 | 78.04±4.12 | 67.80± 4.00 | 73.33 ± 2.36 | 79.36 ± 4.22 | 82.94 ± 2.22 | 90.20± 2.80 | 84.72 ± 3.24 | 85.45 ± 2.80 |
| | 22.22± 0.17 | 51.85± 0.32 | 54.16± 0.17 | 56.01± 0.18 | | | | | 80.19 ± 1.92 | 82.95 ±4.72 | 59.03± 2.38 | 71.85±3.00 | 65.50± 3.77 | 70.58 ± 3.31 | 76.01 ± 1.71 | 74.44 ± 2.03 | 77.74 ± 3.17 | 80.65 ± 2.27 | 80.62 ± 2.71 |
| | | | | | | | | | 77.07 ± 1.13 | 77.50 ±3.12 | 57.04± 2.21 | 64.47±2.44 | | | 72.91 ± 3.30 | 72.00 ± 2.34 | 68.86 ± 1.54 | 76.80 ± 2.61 | 76.09 ± 2.91 |
| | | | | | | | | | | 75.68 ±3.32 | | | | | | 64.00 ± 2.44 | 60.11 ± 1.93 | 63.64 ± 2.18 | |
| | | | | | | | | | | 72.95 ±1.78 | | | | | | | 59.16 ± 3.15 | | |
| | | | | | | | | | | 71.13 ±4.01 | | | | | | | | | |
| .00±0.12 | 77.78± 0.17 | 48.15± 0.59 | 48.84± 0.46 | 43.99± 0.38 | 30.37± 0.84 | 41.97 ± 0.76 | 25.72 ± 1.43 | 16.91 ± 1.62 | 22.93 ± 1.87 | 28.87 ±2.39 | 42.06± 2.38 | 35.53± 3.21 | 34.50± 6.18 | 29.42 ± 2.79 | 27.09 ± 1.83 | 36.00 ± 1.79 | 40.84 ± 1.77 | 36.36 ± 1. 33 | 23.91 ± 2.19 |
| .00±0.50 | 15.55± 1.33 | 9.64± 0.91 | 9.17± 1.50 | 8.78± 1.04 | 10.12± 0.61 | 10.49 ± 0.57 | 6.43 ± 1.40 | 4.23 ± 1.71 | 3.82 ± 0.78 | 3.20 ±0.60 | 7.01± 2.57 | 5.92± 0.89 | 6. 9± 0.30 | 5.88 ± 2.23 | 4.51 ± 0.96 | 5.14 ± 0. 91 | 5.10 ± 1.61 | 5.19 ± 0. 94 | 3.98 ± 2.20 |

* = Standard Error

* = Taking initial weight as 100.00

Mean rate of loss of weight of different instars of Scylla tes aegiptus under starvation with and without desiccation.

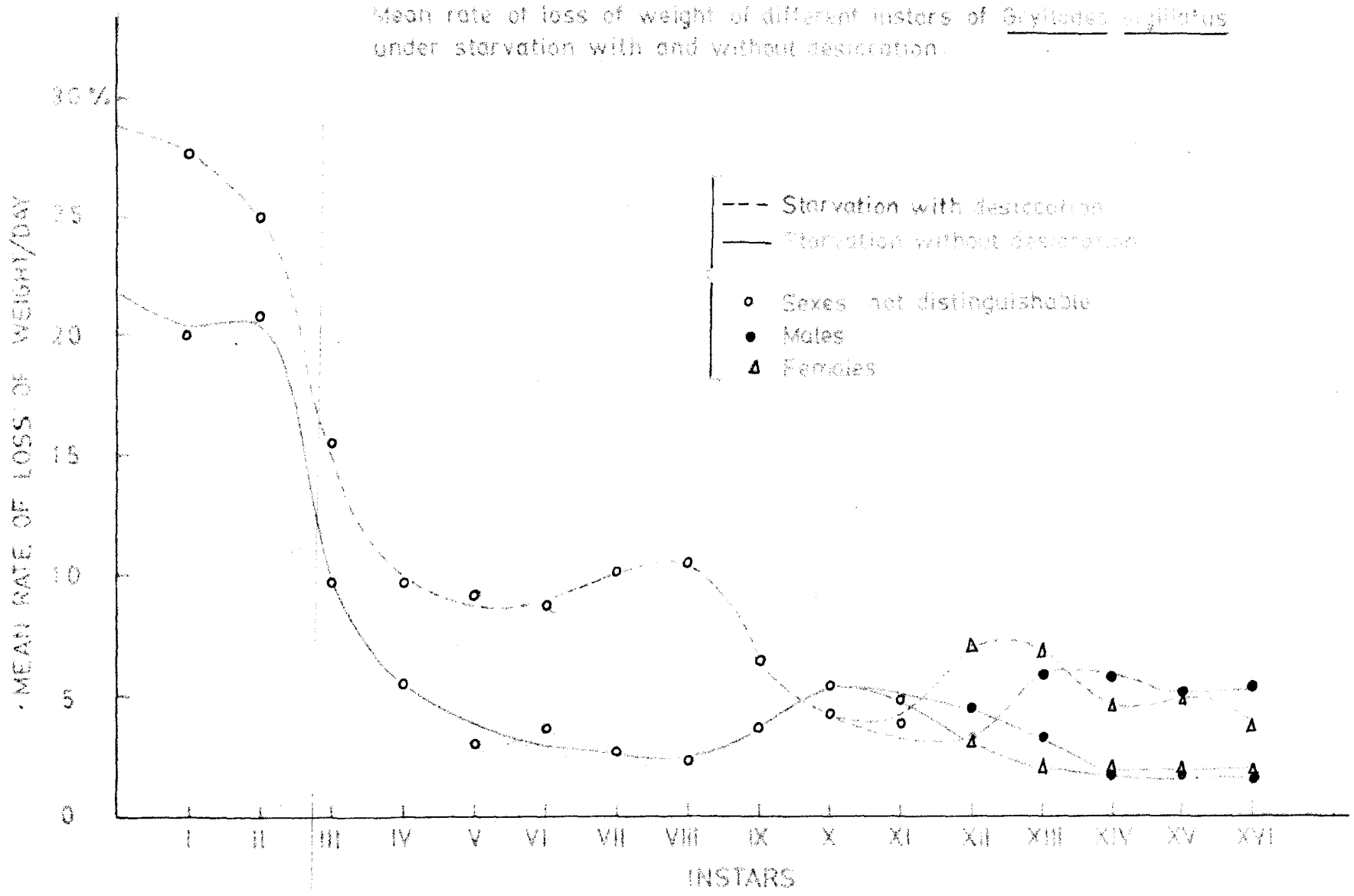


Fig. 2

TABLE-2. Percentage of weight loss due to faecal matter in *Gryllodes sigillatus* Walker during starvation with desiccation at 30 ± 1°C and R.H. 20 ± 5 per cent.

| INSTAR | | INITIAL WEIGHT (mg) | TOTAL WEIGHT OF FAECAL MATTER (mg) | PER CENT LOSS IN WEIGHT DUE TO FAECAL MATTER |
|---|---|---|---|---|
| 1 | | 1.2 | 0.15 | 12.50 |
| 2 | | 1.6 | 0.15 | 9.37 |
| 3 | | 3.6 | 0.30 | 8.33 |
| 4 | | 5.4 | 0.40 | 7.40 |
| 5 | | 9.6 | 0.20 | 2.08 |
| 6 | | 18.23 | 0.60 | 3.29 |
| 7 | | 30.68 | 0.88 | 2.86 |
| 8 | | 45.34 | 1.20 | 2.64 |
| 9 | | 69.24 | 1.20 | 1.73 |
| 10 | | 83.35 | 1.80 | 2.15 |
| 11 | | 92.22 | 2.80 | 3.03 |
| 12 | ♂ | 98.44 | 7.80 | 7.92 |
| | ♀ | 105.21 | 2.40 | 2.28 |
| 13 | ♂ | 100.28 | 6.60 | 6.58 |
| | ♀ | 122.82 | 4.40 | 3.58 |
| 14 | ♂ | 153.22 | 3.00 | 1.95 |
| | ♀ | 158.86 | 2.40 | 1.51 |
| 15 | ♂ | 180.23 | 2.40 | 1.33 |
| | ♀ | 236.02 | 5.20 | 2.20 |
| 16 | ♂ | 201.62 | 2.60 | 1.28 |

in the loss in weight of the male and the female nymphs. But in the thirteenth instar nymphs, both the sexes showed a similarity in the total loss of the weight. The highest rate of loss in weight is in the first instar nymphs ( being 27.78 ± 0.56 percent of the initial weight/day) while it is lowest in the twelfth instar male nymphs (being 3.20 ± 0.60 percent of the initial weight/day). The loss of weight may be due to the expulsion of the faecal matter apart from other factors involved. From Table 2 it is evident that the percentage of loss in weight due to faecal matter is higher in the first few instars as compared with the succeeding instars.

(ii) Effect of starvation without desiccation upon the body weight of instars of Gryllodes sigillatus.

Under the conditions of starvation without desiccation the percent loss in weight in the first and second instar is 66.67 ± 0.11 and 62.5 ± 0.15 respectively of the initial weight (Table 3 ). Under this condition, the total loss in weight was highest in third instar nymphs (78.05 ± 1.97 percent of the initial weight) and lowest in the fifteenth instar males (20.07 ± 2.18 percent of the initial weight). It is also evident that the total loss in weight was less in the older nymphs. The highest rate of loss in weight was found to be in the first instar nymphs (being 20.00 ± 0.06

IGHT PERCENT OF THE DIFFERENT NYMPHAL INSTARS OF Gryllodes sigillatus KEPT UNDER
OUT DESICCATION AT 30 ± 1°C AND 80 ± 5 PERCENT R.H.

| WEIGHT OF INSTARS * | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I | III | IV | V | VI | VII | VIII | IX | X | XI | XII | | XIII | | XIV | | XV | | XVI | | | | | |
| | | | | | | | | | | ♂ | ♀ | ♂ | ♀ | ♂ | ♀ | ♂ | ♀ | ♀ | ♂ | ♀ | | | |
| 0.02 | 100.00± 0.09 | 100.00± 0.00 | 100.00± 1.00 | 100.00± 1.88 | 100.00± 1.22 | 100.00 ± 2.00 | 100.00 ± 1.48 | 100.00± 1.18 | 100.00± 1.10 | 100.00± 1.32 | 100.00± 2.01 | 100.00± 2.12 | 100.00± 1.91 | 100.00 ± 2.62 | 100.00 ± 2.41 | 100.00 ± 1.74 | | 100.00 ± 2.32 | 100.00 ± 2.73 | 100.00 ± 2.18 | | | |
| 0.31 | 97.22± 2.57 | 85.71± 1.38 | 97.95± 2.81 | 98.91± 2.97 | 96.37± 2.18 | 98.75 ± 2.07 | 96.15 ± 1.65 | 96.74± 2.01 | 99.52± 2.51 | 98.57± 1.38 | 98.12± 2.18 | 98.20± 2.18 | 98.20± 2.18 | 97.88 ± 2.71 | 97.41 ± 2.84 | 98.48 ± 3.62 | | 95.42 ± 2.81 | 98.50 ± 3.74 | 98.26 ± 2.19 | | | |
| 0.09 | 83.33± 1.19 | 82.14± 1.18 | 95.91± 2.71 | 95.65± 2.90 | 83.41± 2.28 | 95.75 ± 2.04 | 90.38 ± 1.55 | 79.32± 3.19 | 84.53± 2.31 | 94.52± 1.26 | 96.34± 2.50 | 96.16± 2.74 | 95.35± 2.91 | 96.43 ± 2.80 | 96.53 ± 2.88 | 94.17 ± 4.18 | | 92.63 ± 2.14 | 94.31 ± 3.17 | 93.84 ± 2.31 | | | |
| 0.08 | 77.77± 1.58 | 75.00± 2.07 | 93.87± 2.16 | 91.30± 2.71 | 82.90± 3.11 | 93.50 ± 2.01 | 88.46 ± 1.42 | 73.68± 2.48 | 77.93± 3.72 | 94.29± 1.10 | 90.94± 1.18 | 94.94± 2.76 | 94.13± 2.30 | 96.17 ± 2.81 | 96.63 ± 2.36 | 94.63 ± 2.36 | | 91.36 ± 2.26 | 94.31 ± 3.17 | 91.23 ± 2.88 | | | |
| | 66.66± 1.23 | 68.85± 1.92 | 91.83± 2.31 | 81.52± 2.48 | 79.79± 3.21 | 87.75 ± 2.06 | 85.76 ± 1.06 | 68.53± 2.76 | 76.97± 1.39 | 85.38± 1.68 | 81.21± 2.27 | 85.16± 2.77 | 94.13± 2.30 | 92.28 ± 2.23 | 90.38 ± 2.60 | 90.47 ± 4.32 | | 90.68 ± 2.32 | 93.74 ± 3.08 | 88.10 ± 2.17 | | | |
| | 61.11± 1.51 | 68.85± 1.38 | 91.83± 2.77 | 77.17± 2.99 | 79.29± 3.33 | 83.25 ± 1.92 | 80.00 ± 2.67 | 64.50± 2.97 | 76.49± 1.48 | 80.25± 1.13 | 78.21± 3.00 | 80.76± 2.68 | 92.50± 2.61 | 91.09 ± 2.27 | 88.04 ± 2.44 | 87.97 ± 3.15 | | 90.26 ± 2.87 | 90.85 ± 2.81 | 84.16 ± 3.01 | | | |
| | 55.55± 1.50 | 60.71± 1.91 | 89.79± 2.82 | 68.47± 3.42 | 79.20± 3.54 | 80.80 ± 1.96 | 77.69 ± 2.31 | 59.01± 2.88 | 67.68± 1.37 | 80.06± 2.11 | 75.76± 4.21 | 76.20± 2.51 | 90.87± 2.57 | 88.72 ± 2.10 | 84.91 ± 1.54 | 86.72 ± 3.72 | | 90.09 ± 2.11 | 88.33 ± 4.12 | 80.33 ± 2.07 | | | |
| | 33.33± 1.81 | 57.14± 1.73 | 85.71± 2.72 | 67.39± 2.89 | 79.19± 3.77 | 80.00 ± 2.12 | 76.92 ± 2.47 | 55.01± 2.71 | 67.14± 1.85 | 78.06± 2.87 | 71.72± 1.83 | 76.28± 2.34 | 86.48± 2.43 | 88.19 ± 2.12 | 84.57 ± 2.25 | 85.51 ± 3.18 | | 86.28 ± 2.08 | 86.08 ± 5.44 | 77.05 ± 2.84 | | | |
| | 21.95± 1.71 | 53.57± 1.88 | 83.67± 2.13 | 65.21± 2.77 | 78.27± 2.87 | 79.75 ± 2.78 | 74.42 ± 2.58 | 51.87± 2.30 | 61.15± 1.80 | 72.42± 1.38 | 70.10± 1.41 | 74.97± 3.10 | 81.92± 2.48 | 86.60 ± 2.13 | 82.67 ± 3.10 | 84.39 ± 3.70 | | 85.30 ± 2.32 | 85.02 ± 3.51 | 78.23 ± 2.01 | | | |
| | | 50.00± 2.12 | 79.59± 3.03 | 64.13± 3.76 | 76.16± 3.10 | 78.50 ± 1.81 | 72.30 ± 3.55 | 50.12± 2.80 | | 68.81± 1.78 | 68.00± 2.91 | 70.57± 2.38 | 80.46± 2.91 | 85.81 ± 2.12 | 81.92 ± 2.37 | 83.58 ± 2.00 | | 84.29 ± 2.95 | 84.30 ± 2.18 | 75.89 ± 3.02 | | | |
| | | | 77.55± 3.92 | 64.13± 2.62 | 73.05± 2.88 | 76.00 ± 1.91 | 70.76 ± 3.04 | | | 55.70± 1.99 | 67.64± 2.41 | 67.15± 2.17 | 78.16± 2.50 | 82.10 ± 2.82 | 80.09 ± 2.88 | 81.86 ± 2.88 | | 86.16 ± 2.38 | 82.71 ± 2.38 | 74.84 ± 2.31 | | | |
| | | | 67.34± 1.81 | 60.86± 3.12 | 70.20± 3.35 | 70.00 ± 1.84 | 64.80 ± 2.38 | | | | 64.82± 2.99 | 66.25± 2.89 | 77.76± 2.10 | 80.60 ± 2.03 | 77.85 ± 2.06 | 81.15 ± 2.22 | | 77.34 ± 2.71 | 81.99 ± 2.81 | 73.15 ± 3.89 | | | |
| | | | 63.17± 1.27 | 55.40± 2.12 | 67.35± 2.31 | 69.50 ± 2.27 | 57.52 ± 1.12 | | | | | 60.79± 3.20 | 74.18± 2.91 | 77.58 ± 1.68 | 76.01 ± 2.90 | 79.93 ± 2.18 | | 77.30 ± 2.86 | 80.78 ± 2.72 | 70.53 ± 3.09 | | | |
| | | | | | | 69.00 ± 2.21 | 51.15 ± 2.22 | | | | | | 71.98± 2.31 | | 73.84 ± 2.72 | | | 75.65 ± 2.15 | 79.48 ± 2.12 | 69.18 ± 2.48 | | | |
| | | | | | | | | | | | | | | | 71.33 ± 2.10 | | | 74.17 ± 2.33 | 77.90 ± 2.78 | 67.41 ± 2.57 | | | |
| | | | | | | | | | | | | | | | | | | 72.33 ± 2.18 | 77.40 ± 2.71 | 66.41 ± 1.98 | | | |
| | | | | | | | | | | | | | | | | | | 71.21 ± 1.17 | | 66.23 ± 2.01 | | | |
| | | | | | | | | | | | | | | | | | | 68.54 ± 2.76 | | 65.25 ± 2.12 | | | |
| | | | | | | | | | | | | | | | | | | 66.37 ± 2.66 | | 64.70 ± 2.27 | | | |
| 25 | 78.05± 1.97 | 50.00± 1.82 | 36.83± 1.12 | 44.60± 1.98 | 32.65± 2.88 | 31.00 ± 3.27 | 48.85 ± 3.18 | 49.88± 4.12 | 38.85± 6.12 | 44.30± 3.13 | 35.18± 2.88 | 39.21± 2.16 | 78.02± 2.38 | 22.42 ± 2.10 | 28.61 ± 2.01 | 20.07 ± 2.18 | | 33.03 ± 3.18 | 22.59 ± 2.10 | 35.30 ± 1.81 | | | |
| 13 | 9.75± 0.22 | 5.55± 1.36 | 3.06± 0.73 | 3.71± 0.88 | 2.72± 1.16 | 2.38 ± 1.48 | 3.75 ± 1.24 | 5.45± 2.09 | 4.85± 2.03 | 4.43± 0.67 | 3.19± 0.80 | 3.26± 0.77 | 2.15± 0.48 | 1.86 ± 0.18 | 2.04 ± 0.29 | 1.67 ± 0.32 | | 1.83 ± 0.38 | 1.50 ± 0.25 | 1.96 ± 0.70 | | | |

S.E. = Standard Error

* = Taking initial weight as 100.00

TABLE-4. Percentage of weight loss due to faecal matter in *Gryllodes sigillatus* Walker during starvation without desiccation at 30 ± 1°C and R.H. 80 ± 5 per cent.

| INSTAR | | INITIAL WEIGHT (mg) | TOTAL WEIGHT OF FAECAL MATTER (mg) | PER CENT LOSS IN WEIGHT DUE TO FAECAL MATTER |
|---|---|---|---|---|
| 1 | | 1.20 | 0.15 | 12.50 |
| 2 | | 1.60 | 0.15 | 9.37 |
| 3 | | 3.60 | 0.30 | 8.33 |
| 4 | | 5.60 | 0.30 | 5.35 |
| 5 | | 9.80 | 0.40 | 4.08 |
| 6 | | 18.43 | 0.40 | 2.17 |
| 7 | | 38.62 | 0.40 | 1.03 |
| 8 | | 48.00 | 2.40 | 5.00 |
| 9 | | 68.22 | 2.20 | 3.22 |
| 10 | | 81.82 | 4.50 | 5.49 |
| 11 | | 94.45 | 2.70 | 2.85 |
| 12 | ♂ | 100.68 | 3.60 | 3.57 |
| | ♀ | 108.11 | 2.60 | 2.40 |
| 13 | ♂ | 100.71 | 3.80 | 3.77 |
| | ♀ | 123.82 | 3.90 | 3.14 |
| 14 | ♂ | 151.62 | 3.22 | 2.12 |
| | ♀ | 186.25 | 4.70 | 2.52 |
| 15 | ♂ | 197.49 | 3.60 | 1.82 |
| | ♀ | 236.25 | 7.30 | 3.08 |
| 16 | ♂ | 207.63 | 4.30 | 2.07 |

percent of the initial weight/day) and the lowest in the sixteenth instar females (being 1.50 ± 0.25 percent of the initial weight/day) while in the sixteenth instar female nymphs it was observed to be 1.96 ± 0.70 percent of the initial weight/day respectively. There is a variation in the total loss of weight (percent of the initial), amount of loss per day and in the time of survival of each male and female nymph. Table 4 shows loss of weight due to expulsion of faecal matter in each instar which is higher in first few instars as compared with the rest.

From Fig.2, it is evident that the rate of loss of weight under starvation with desiccation is always higher in all instars except the tenth, eleventh and only in the males of the twelfth instar, than those under starvation without desiccation. The rate of loss of weight in instars showed two sharp peaks in eighth and twelfth instar females under the conditions of starvation with desiccation. Whereas in case of nymphs under starvation without desiccation there is gradual drop in the rate of loss of weight. The rate of loss of weight in female nymphs during starvation with desiccation was higher than in those without desiccation. In case of male desiccated nymphs it was slightly more than in those without desiccation except the eleventh and the twelfth instar. Curiously, it has been observed that the twelfth to sixteenth

instars nymphs under starvation without desiccation develop cannibalistic habits. When kept in isolation they consume their own parts of the body like antennae and the hind leg tarsi. The female nymphs consume their own cerci as food. This strange behaviour may be observed after few days of starvation. This 'autocannibalism' has been observed from seventh to sixteenth instar nymphs under the conditions of starvation without desiccation in which the nymphs consume a portion of their antennae and hind leg.

The survival of the nymphs differs in both the conditions of starvation. First, second, seventh and eighth instar nymphs survived for 3 days under starvation with desiccation while similar results were obtained in the first and second instar nymphs survived for 12 and 13 days respectively under starvation without desiccation. The survival of the nymphs is affected under starvation with desiccation and the nymphs survived for a lesser period than their counterparts under starvation without desiccation (Table 1 and 3). The third, fourth, fifth, sixth, thirteenth female and fourteenth male instar nymphs survived for a period of 5 days whereas the ninth and tenth instar nymphs survived for 4 days under this condition ( Table 1 ).

Eleventh, twelfth female, thirteenth male, fourteenth female and sixteenth female instar nymphs survived for a period of 6 days and fifteenth male and sixteenth male instar nymphs survived for a period of 7 days respectively. The fifteenth instar female nymphs survived for 8 days while twelfth instar male nymphs survived for 9 days under this condition of starvation with desiccation (Table 1). Under the condition of starvation without desiccation the survival time varied from 3 days to 18 days as was seen in case of first, second instar nymphs and in fifteenth instar female and sixteenth instar female nymphs respectively. Females lived longer than the males in this condition (Table 3)

(iii) Effect of starvation with desiccation upon loss in weight and water content of the body of instars of Gryllodes sigillatus.

It is evident from Table 5 that the loss in weight and water content varies from instar to instar under starvation with desiccation. The water content varied from 30.00 per cent in first instar to 81.95 per cent in sixteenth instar female nymphs. The water content is higher in the female instar nymphs than in the male instar nymphs except in twelfth instar where the water content of male nymphs is higher than the female instar nymphs. The loss in body weight varied from 83.33 per cent in the first instar nymphs to 16.91 per cent in tenth instar nymphs. The loss in weight is variable in the sexes.

TABLE-5. EFFECTS OF STARVATION WITH DESICCATION ON LOSS IN WEIGHT, WATER CONTENT AND SURVIVAL OF INSTARS OF *Cryllodes sigillatus* Walker. At 30 ± 1° and R.H. 20 ± 5 Per cent

| 1 | 2 | (1-2) | | Total time | a | b | (a - b) | |
|---|---|---|---|---|---|---|---|---|
| Average wt. of an individual before starvation. | Average wt. of an individual after starvation till death | Loss in weight | | of starvation (Survival) | Average weight of an individual before keeping in oven at 110° C. | Average wt. of an individual after keeping in oven for 24 hours. | Loss in weight i.e., Water content | |
| mg. | mg. | mg. | Per cent | | mg | mg | mg. | Percent |
| 1.2 | 0.2 | 1.0 | 83.33% | 3 | 0.20 | 0.14 | 0.06 | 30.00% |
| 1.6 | 0.4 | 1.2 | 75.00% | 3 | 0.40 | 0.25 | 0.15 | 37.50% |
| 3.6 | 0.8 | 2.8 | 77.77% | 5 | 0.80 | 0.40 | 0.40 | 50.00% |
| 5.4 | 2.8 | 2.6 | 48.14% | 5 | 2.80 | 0.85 | 1.95 | 69.64% |
| 9.6 | 5.2 | 4.4 | 45.83% | 5 | 5.20 | 1.83 | 3.37 | 64.80% |
| 18.23 | 10.21 | 8.02 | 43.99% | 5 | 10.21 | 2.80 | 7.41 | 72.57% |
| 30.68 | 21.36 | 9.32 | 30.37% | 3 | 21.36 | 4.20 | 17.16 | 80.33% |
| 45.34 | 26.31 | 19.03 | 41.97% | 4 | 26.31 | 8.40 | 17.91 | 68.07% |
| 69.24 | 52.06 | 17.81 | 25.72% | 4 | 52.06 | 20.00 | 32.06 | 61.58% |
| 83.35 | 69.25 | 14.10 | 16.91% | 4 | 69.25 | 25.02 | 44.23 | 63.87% |
| 92.22 | 71.07 | 21.15 | 22.93% | 6 | 71.07 | 27.23 | 43.84 | 61.67% |
| 98.44 | 70.02 | 28.42 | 28.87% | 9 | 70.02 | 29.45 | 40.62 | 58.00% |
| 105.21 | 60.95 | 44.26 | 42.06% | 6 | 60.95 | 29.03 | 31.92 | 52.37% |
| 100.28 | 64.65 | 35.63 | 35.53% | 6 | 64.65 | 28.81 | 35.84 | 55.43% |
| 122.82 | 80.44 | 42.38 | 34.50% | 5 | 80.44 | 27.89 | 52.55 | 65.32% |
| 153.22 | 108.14 | 45.08 | 29.42% | 5 | 108.14 | 29.22 | 78.92 | 72.97% |
| 158.86 | 115.82 | 43.04 | 27.09% | 6 | 115.82 | 28.42 | 87.40 | 79.46% |
| 180.23 | 115.34 | 69.89 | 36.00% | 7 | 115.34 | 30.21 | 85.13 | 73.80% |
| 236.02 | 139.62 | 96.40 | 40.84% | 8 | 139.62 | 30.32 | 109.30 | 78.28% |
| 201.62 | 128.31 | 73.31 | 36.36% | 7 | 128.31 | 32.48 | 95.83 | 74.68% |
| 249.26 | 189.67 | 59.59 | 23.90% | 6 | 189.67 | 34.22 | 155.45 | 81.95% |

In twelfth and fifteenth instar nymphs the weight loss is greater in females than in males but in thirteenth, fourteenth and sixteenth instar nymphs it is greater in males than in females. The total time of starvation till death also varied from instar to instar. It varies from 3 days in first instar nymphs to 9 days in twelfth instar male nymphs. In sixteenth instar nymphs it was 7 and 6 days for males and females respectively.

(iv) Effect of starvation without desiccation upon loss in weight and water content of the body of instars of Gryllodes sigillatus.

It is evident from Table 6 that the loss in weight and water content under starvation without desiccation varied from instar to instar. The water content varies from 83.46 per cent in seventh instar nymphs to 38.87 per cent in tenth instar nymphs. It is 66.66 per cent in the first instar nymphs and 79.56 per cent and 79.32 per cent in males and females of sixteenth instar respectively. The water content is higher in female nymphs than the male nymphs except in fifteenth and sixteenth instar nymphs. The loss in body weight varies from 20.07 per cent in males of fifteenth instar nymphs to 78.05 per cent in third instar nymphs. It is 50.00 per cent in first instar nymphs and 22.59 per cent and 35.30 per cent in males and females of sixteenth instar nymphs respectively. The total time of starvation till death varies from 3 days in first and second instar nymphs to 18

TABLE-6. EFFECTS OF STARVATION WITH DESICCATION ON LOSS IN WEIGHT, WATER CONTENT AND SURVIVAL OF INSTARS OF

*Gryllodes sigillatus* Walker. At 30 ± 1°C AND R.H. 80± 5 PER CENT

| SEX | 1 | 2 | (1-2) | | Total time of starvation (Survival) | a | b | (a - b) | |
|---|---|---|---|---|---|---|---|---|---|
| | Average wt. of an individual before starvation. | Average wt. of an individual after starvation till death. | Loss in weight | | | Average weight of an individual before keeping in oven at 110°C. | Average wt. of an individual after keeping in oven for 24 hours. | Loss in weight i.e. water content | |
| | mg. | mg. | mg. | Percent | Days | mg. | mg. | mg. | Per cent |
| | 1.20 | 0.60 | 0.60 | 50.00% | 3 | 0.60 | 0.20 | 0.40 | 66.66% |
| | 1.60 | 0.60 | 1.00 | 62.50% | 3 | 0.60 | 0.25 | 0.35 | 58.33% |
| | 3.60 | 0.79 | 2.81 | 78.05% | 8 | 0.79 | 0.41 | 0.38 | 48.10% |
| | 5.60 | 2.80 | 2.80 | 50.00% | 9 | 2.80 | 0.85 | 1.95 | 69.64% |
| | 9.80 | 6.19 | 3.61 | 36.83% | 12 | 6.19 | 1.82 | 4.37 | 70.59% |
| | 18.43 | 10.21 | 8.22 | 44.60% | 12 | 10.21 | 2.83 | 7.38 | 72.28% |
| | 38.62 | 26.01 | 12.61 | 32.65% | 12 | 26.01 | 4.30 | 21.71 | 83.46% |
| | 48.00 | 33.12 | 14.88 | 31.00% | 13 | 33.12 | 8.62 | 24.40 | 73.97% |
| | 68.22 | 34.89 | 33.33 | 48.85% | 13 | 34.89 | 20.83 | 14.06 | 40.29% |
| | 81.82 | 41.00 | 40.82 | 49.89% | 9 | 41.00 | 25.06 | 15.94 | 38.87% |
| | 94.45 | 57.75 | 36.70 | 38.85% | 8 | 59.75 | 27.55 | 32.20 | 55.75% |
| ♂ | 100.68 | 56.07 | 44.61 | 44.30% | 10 | 56.07 | 28.32 | 27.75 | 49.49% |
| ♀ | 108.11 | 70.07 | 38.04 | 35.18% | 11 | 70.07 | 29.48 | 40.59 | 57.92% |
| ♂ | 100.71 | 61.22 | 39.49 | 39.21% | 12 | 61.22 | 29.08 | 32.21 | 52.61% |
| ♀ | 123.82 | 89.12 | 34.70 | 28.02% | 13 | 89.12 | 28.10 | 61.02 | 68.46% |
| ♂ | 151.62 | 117.62 | 34.00 | 22.42% | 12 | 117.62 | 28.92 | 88.70 | 75.41% |
| ♀ | 186.25 | 131.95 | 53.30 | 28.61% | 14 | 131.95 | 30.00 | 101.95 | 77.26% |
| ♂ | 197.49 | 157.85 | 39.64 | 20.07% | 12 | 157.85 | 30.10 | 127.75 | 80.93% |
| ♀ | 236.25 | 158.21 | 78.04 | 33.03% | 18 | 158.21 | 32.10 | 126.11 | 79.71% |
| ♂ | 207.63 | 160.72 | 49.91 | 22.59% | 15 | 160.72 | 32.84 | 127.88 | 79.56% |
| ♀ | 241.48 | 156.22 | 85.26 | 35.30% | 18 | 156.22 | 32.29 | 123.92 | 79.32% |

(V) Comparison of loss in weight and water content of the body of instars of Gryllodes sigillatus under the conditions of starvation with and without desiccation.

The comparison of the weight loss and the water content under the conditions of starvation with and without desiccation is included in Table 7. The comparison of water content from first to eleventh instar nymphs showed that under the condition of starvation with desiccation the water content is 30.00 per cent in the first instar nymphs and 61.67 per cent in eleventh instar nymphs. While under the condition of starvation without desiccation the water content is 66.66 per cent in the first instar nymphs and 55.75 per cent in eleventh instar nymphs. The minimum water content from first to eleventh instar is 30.00 per cent in case of first instar nymphs but the minimum water content in this range (from first to eleventh instar nymphs) under the conditions of starvation without desiccation has been observed to be 38.87 per cent in tenth instar nymphs. The maximum water content from first to eleventh instar nymphs is 80.33 per cent in seventh instar nymphs under starvation with desiccation whereas the maximum water content under the conditions of starvation without desiccation is 83.46 per cent in seventh instar nymphs. The loss in body weight is 83.33 per cent in first instar nymphs and 22.93 per cent in eleventh instar nymphs under starvation with desiccation and 50.00 per cent and 38.85 per cent in their counterparts under starvation without desiccation condition.

AND STARVATION WITHOUT DESICCATION (30 ± 1°C and R.H. 80 ± 5 per cent ) ON THE LOSS IN WEIGHT, WATER CONTENT AND SURVIVAL OF THE INSTARS OF *Cryllodes sigillatus* Walker.

| | STARVATION WITH DESICCATION | | | STARVATION WITHOUT DESICCATION | | |
|---|---|---|---|---|---|---|
| SEX | LOSS IN BODY WEIGHT | TOTAL TIME OF STARVATION | WATER CONTENT | LOSS IN BODY WEIGHT | TOTAL TIME OF STARVATION | WATER CONTENT |
| | Per cent | Days | Per cent | Per cent | Days | Per cent |
| | 83.33% | 3 | 30.00% | 50.00% | 3 | 66.66% |
| | 75.00% | 3 | 37.50% | 62.50% | 3 | 58.33% |
| | 77.77% | 5 | 50.00% | 78.05% | 8 | 48.10% |
| | 48.14% | 5 | 69.64% | 50.00% | 9 | 69.64% |
| | 45.83% | 5 | 64.80% | 36.83% | 12 | 70.59% |
| | 43.99% | 5 | 72.57% | 44.60% | 12 | 72.28% |
| | 30.37% | 3 | 80.33% | 32.65% | 12 | 83.46% |
| | 41.97% | 4 | 68.07% | 31.00% | 13 | 73.97% |
| | 25.72% | 4 | 61.58% | 48.85% | 13 | 40.29% |
| | 16.91% | 4 | 63.87% | 49.89% | 9 | 38.87% |
| | 22.93% | 6 | 61.67% | 38.85% | 8 | 55.75% |
| ♂ | 28.87% | 9 | 58.00% | 44.30% | 10 | 49.49% |
| ♀ | 42.06% | 6 | 52.37% | 35.18% | 11 | 57.92% |
| ♂ | 35.53% | 6 | 55.43% | 39.21% | 12 | 52.61% |
| ♀ | 34.50% | 5 | 65.32% | 28.02% | 13 | 68.46% |
| ♂ | 29.42% | 5 | 72.97% | 22.42% | 12 | 75.41% |
| ♀ | 27.09% | 6 | 79.46% | 28.61% | 14 | 77.26% |
| ♂ | 36.00% | 7 | 73.80% | 20.07% | 12 | 80.93% |
| ♀ | 40.84% | 8 | 78.28% | 33.03% | 18 | 79.71% |
| ♂ | 36.36% | 6 | 74.68% | 22.59% | 15 | 79.56% |
| ♀ | 23.90% | 7 | 81.95% | 35.30% | 18 | 79.32% |

The maximum and minimum weight loss are 83.33 per cent in the first instar nymphs and 16.91 per cent in the tenth instar nymphs under starvation with desiccation condition. Under the condition of starvation without desiccation wthe maximum and minimum weight loss are 78.05 per cent and 31.00 per cent in the third and eighth instar nymphs respectively. The total time of starvation till death of nymphs from first to eleventh instar is minimum (3 days) in first instar nymphs and maximum (6 days) in eleventh instar nymphs under starvation with desiccation condition. The total time of starvation till death of this range of instars under the condition of starvation without desiccation is 3 days in first instar nymphs and 8 days in eleventh instar nymphs. The minimum time of survival (3 days) is in first instar and maximum (13 days) in eighth and ninth instar nymphs. In the sexes, the water content is 58.00 per cent in males of twelfth instar and 74.68 per cent in sixteenth instar male nymphs under the condition of starvation with desiccation. In males the lowest water content (55.43 per cent) has been observed in thirteenth instar and highest water content (74.68 per cent) in sixteenth instar under this condition. While under the condition of starvation without desiccation the water content is 49.49 per cent in twelfth instar males and 79.56 per cent in sixteenth instar males and 79.56 per cent in sixteenth instar male nymphs. Under this condition the minimum and maximum water content among male instars are 49.49 per cent

and 30.93 per cent in twelfth and fifteenth instar nymphs respectively. The minimum loss in weight (28.87 per cent) has been observed in twelfth instar males and maximum loss in weight (36.36 per cent ) among males in sixteenth instar under starvation with desiccation condition. The loss in body weight is 44.30 per cent in twelfth instar male nymphs and 22.59 per cent in sixteenth instar male nymphs under starvation without desiccation. The minimum and maximum loss in weight are 20.07 per cent in fifteenth and 44.30 per cent in twelfth instar male nymphs under this condition. The time of starvation till death varies from 5 days to 9 days under starvation with desiccation. The male nymphs of twelfth instar survived for 9 days whereas the male nymphs of sixteenth instar survived for 6 days under this condition. Under starvation without desiccation the minimum and maximum survival time for males are 10 days in twelfth instar and 15 days in sixteenth instar respectively. In the female nymphs it has been observed that the water content is 52.37 per cent in twelfth instar nymphs and 81.35 per cent in sixteenth instar nymphs under starvation with desiccation, while it is 57.92 per cent in twelfth instar nymphs and 79.32 per cent in sixteenth instar nymphs under the condition of starvation without desiccation. Among the female nymphs, the minimum and maximum water content are 52.37 per cent in twelfth instar and 81.35 per cent in sixteenth instar nymphs under starvation with desiccation.

Under the condition of starvation without desiccation the minimum and maximum water content in female nymphs are 57.92 per cent in twelfth instar and 79.71 per cent in fifteenth instar nymphs respectively. The loss in body weight in females is 42.06 per cent in twelfth instar nymphs and 23.30 per cent in sixteenth instar nymphs under starvation with desiccation. The minimum weight loss is in sixteenth instar female nymphs and maximum loss of weight is in twelfth instar female nymphs under this condition. Under starvation without desiccation the weight loss in females is 35.18 per cent in twelfth instar nymphs and 35.30 per cent in sixteenth instar nymphs. The minimum and maximum weight loss in females under this condition are 28.02 per cent in thirteenth instar and 35.30 per cent in sixteenth instar respectively. The total time of survival for females is 6 days in twelfth instar nymphs and 7 days in sixteenth instar nymphs under starvation with desiccation. The minimum and maximum survival time in females are 5 days in thirteenth instar and 8 days in fifteenth instar nymphs under this condition. The total time of survival for females under starvation without desiccation is 11 days in twelfth instar nymphs and 18 days in sixteenth instar nymphs. The minimum and maximum survival time for females under this condition are in twelfth and sixteenth instar nymphs.

## Statistical Analysis of the Data

Under starvation with desiccation conditions (Table 5) average weight of 21 individuals (nymphs of Gryllodes sigillatus at the following stages has been considered:

1. before starvation ( $X_1$ )
2. after starvation till death ( $X_2$ )
3. after keeping in oven for 24 hours ( $X_3$ )

Correlation coefficients between ( $X_1$, $X_2$ ) and ( $X_1$, $X_3$ ) are calculated and found to be $r_1$= 0.8871 and $r_2$= 0.9899 respectively. In order to compare the two correlation coefficient we make use of the Z - transformation. For this we define $Z_i = \frac{1}{2} \log \frac{1 + r_i}{1 - r_i}$, i = 1,2. It is easy to see that $Z_1$= 2.641692 and $Z_2$=1.40815.

We form the hypothesis as follows:-

$H_o$: Population correlations between ( $X_1$,$X_2$ ) and ($X_1$,$X_3$) are the same.

$H_1$: Population correlations between ($X_1$, $X_2$) and ($X_1$,$X_3$) are significantly different.

In order to test $H_o$ against $H_1$ we compute $Z = (Z_1 - Z_2) / \left( \frac{1}{n_1 - 3} + \frac{1}{n_2 - 3} \right)$ where $Z_1$ and $Z_2$ are as obtained above and $n_1$=$n_2$=21 ( the no. of individuals). Since Z as defined above is a Standard Normal Variate under $H_o$, we reject $H_o$ at 5%

level of significance if the calculated value of Z exceeds 1.96. In our case, Z comes out to be 3.7024, hence the conclusion that there is a significant difference between the two correlation coefficients.

Similarly under starvation without desiccation conditions (Table 6) average weight of 21 individuals (nymphs of Gryllodes sigillatus) at the following stages has been considered:

1. before starvation ( $Y_1$)
2. after starvation till death ($Y_2$)
3. after keeping in oven for 24 hours ($Y_3$)

Correlation coefficients between ( $Y_1, Y_2$ ) and ($Y_1, Y_3$) are calculated and found to be $r_1 = 0.9865$ and $r_2 = 0.6920$ respectively. In order to compare the two correlation coefficients, we make use of the Z- transformation. For this we define $Z_i = \frac{1}{2} \log \frac{1 + r_i}{1 - r_i}$, $i = 1, 2$ . It is easy to see that $Z_1 = 2.4957361$ and $Z_2 = 0.8517838$.

We form the hypothesis as follows:

$H_0$: Population correlations between ( $Y_1, Y_2$) and ($Y_1, Y_3$) are the same.

$H_1$: Population correlations between ($Y_1, Y_2$) and ($Y_1, Y_3$) are significantly different.

In order to test $H_o$ against $H_1$ we compute $Z = (Z_1 - Z_2)/$ $\left( \frac{1}{n_1 - 3} + \frac{1}{n_2 - 3} \right)$ where $Z_1$ and $Z_2$ are as obtained above and $n_1 = n_2 = 21$ ( the number of individuals). Since Z as defined above is a Standard Normal variate under $H_o$, we reject $H_o$ at 5% level of significance if the calculated value of Z exceeds 1.96. In our case, Z comes out to be 4.0309, hence the conclusion that there is a significant difference between the two correlation coefficients.

(VI) Effect of starvation with and without desiccation upon sexual behaviour of adults of Gryllodes sigillatus.

The sound production in crickets is by tegminal stridulation (Alexander, 1967). In Gryllodes sigillatus, the wings are raised which move rapidly and sound is produced. The calling song was heard during nights as well as in day. It is very common type of sound in houses at early hours of the night. The calling song of the males attracts the sexually receptive female (Alexander, 1967). The males produced aggressive song in presence of another male and the male tried to push back the other male. The characteristic courtship songs were produced by males in presence of conspecific females. The tape-recorded courtship song consists of few chirps 3-6/ sec. The chirps contain 1-3 pulses each. The courtship song consists of 5-10 minutes of singing at slow pulse rate, low voice, the

Sound production in crickets has been studied. Three distinct types of songs have been observed in males of Gryllodes sigillatus-calling songs, courtship songs and aggressive songs. Studies have been made on the courtship songs and have been recorded in figures 3 and 4. In Fig.(3) chirp rates have been recorded by X - Y recorder under starvation with desiccation while in Fig.(4) chirp rate have been recorded under the condition of starvation without desiccation. Different representative audiospectrograms of courtship songs of Gryllodes sigillatus under the condition of starvation with and without desiccation are presented in Figs. 5 and 6. In Gryllodes sigillatus, the modal frequency is 4.67 kHz (Figs.5 and 6). The frequency in courtship song is least affected by the conditions of starvation with and without desiccation (Figs.5 and 6). The chirp rate (chirps/sec.) in the starved condition varies from 3.26 chirps/sec.to 5 chirps/sec. while it is 5 chirps/sec. in the normal condition at 30°C and 70% R.H. (Fig.4). The intensity of the courtship song is variable even under the normal condition but it becomes too feeble as the starvation with desiccation prolongs (Fig.3). Three pulses may be observed in each chirp (Figs.5 and 6). These pulses vary from 1-3 in each chirp in the courtship song.

The sexual behaviour of Gryllodes sigillatus under starvation with desiccation and without desiccation has been

Fig.3. Various types of chirps rate in courtship song of *Gryllodes sigillatus* Walker after 0 hour (A), 24 hours (B), 48 hours (C) and 72 hours (D) of starvation with desiccation at 30 ± 1°C and 20 ± 5% R.H.

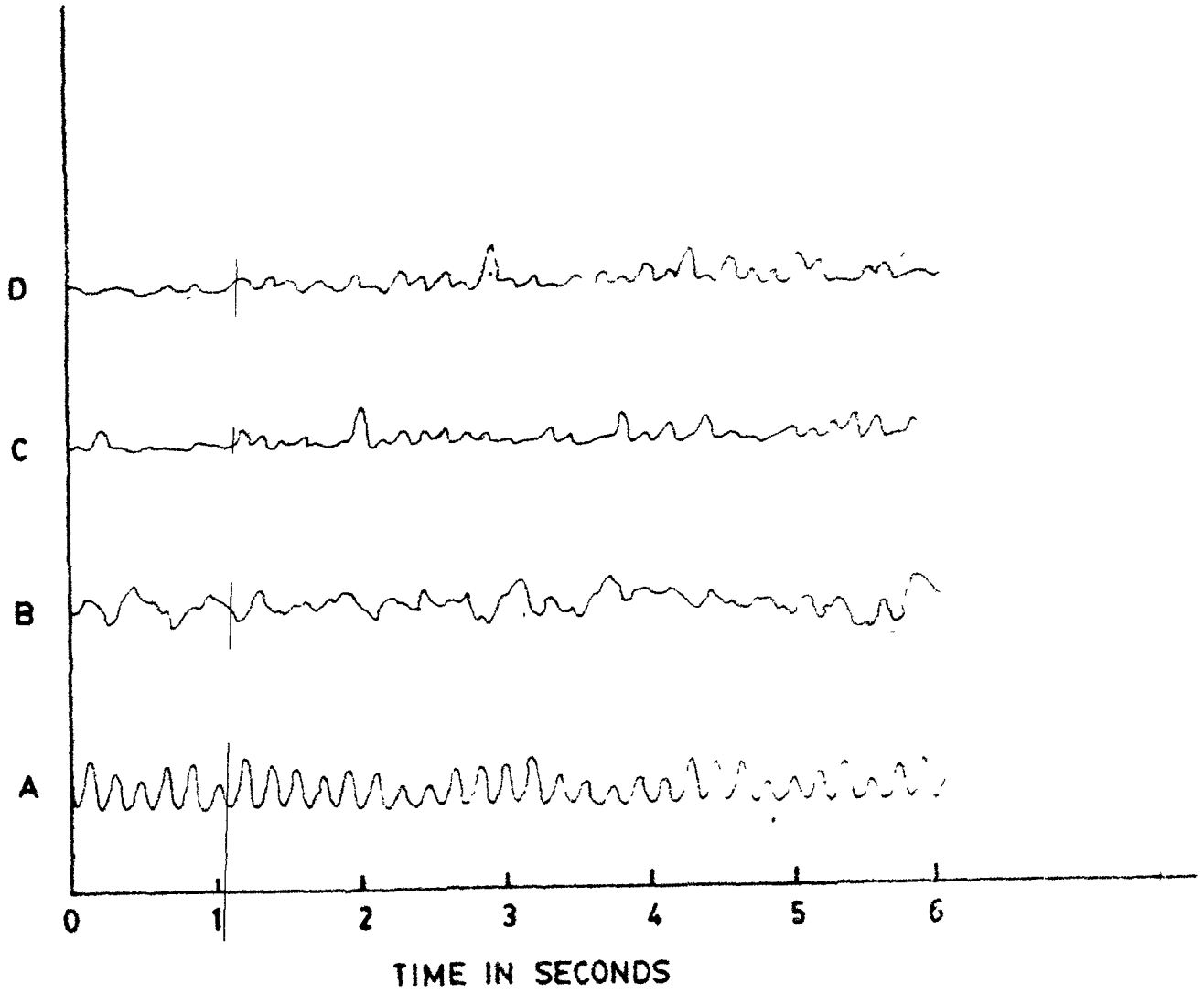


Fig. 3

Fig.4. Various types of chirp rates in courtship song of *Gryllodes sigillatus* Walker after 0 hour (A); 24 hours (B); 48 hours (C); 72 hours (D) and 96 hours (E) of starvation without desiccation at 30 ± 1°C and 80 ± 5% R.H.

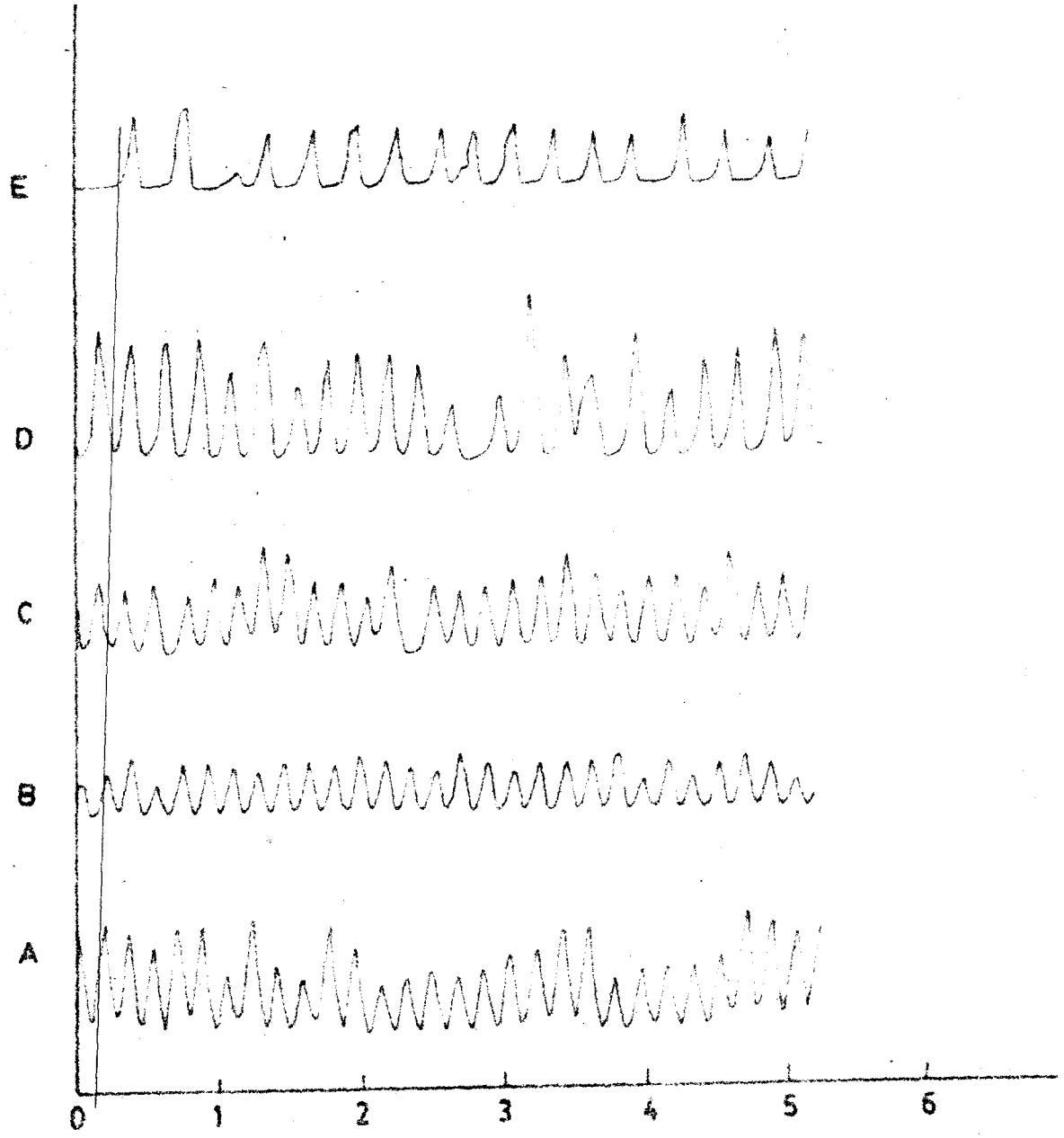


Fig.4

Fig.5. Audiospectrographs showing the frequency and pulses of sound of the male of Gryllodes sigillatus Walker under starvation with desiccation at 30 ± 8°C and R.H. 20 ± 5 per cent at the starvation periods of 0 hours (A) 24 hours (B), 48 hours (C) and 72 hours (D).

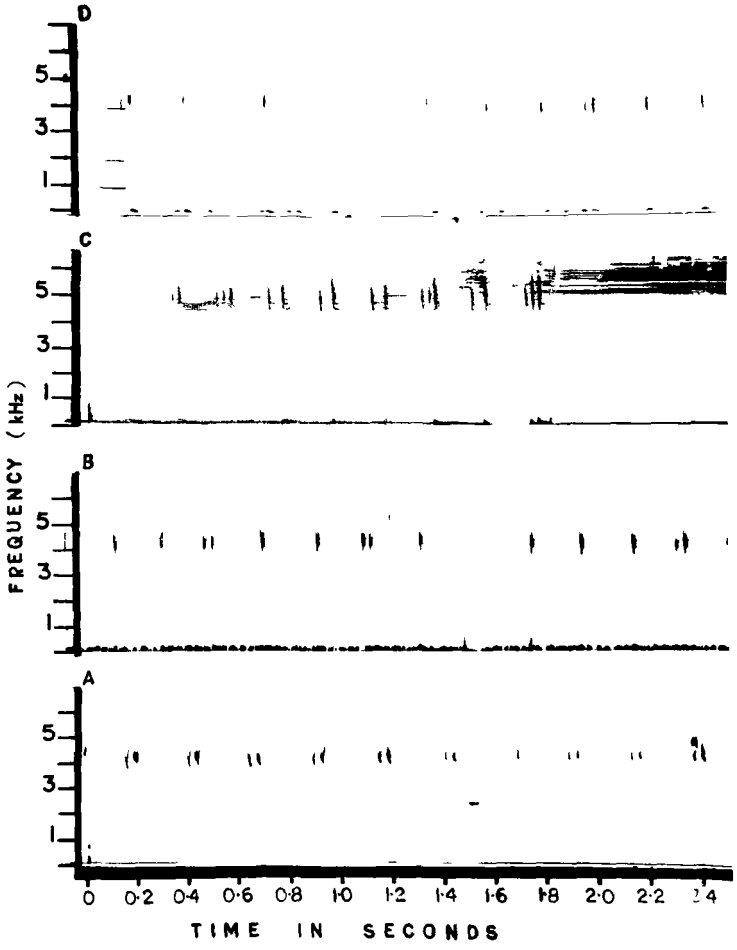
D
C
B
A
5
3
1
FREQUENCY (kHz)
0
0·2
0·4
0·6
0·8
1·0
1·2
1·4
1·6
1·8
2·0
2·2
2·4
TIME IN SECONDS

Fig. 6. Audiospectrographs showing the frequency and pulses of sound of the male of Gryllodes sigillatus Walker under starvation without desiccation at 30 ± 1°C and R.H. 80 ± 5 per cent at the starvation periods of 0 hour (A), 24 hours (B), 48 hours (C), 72 hours (D) and 96 hours (D).

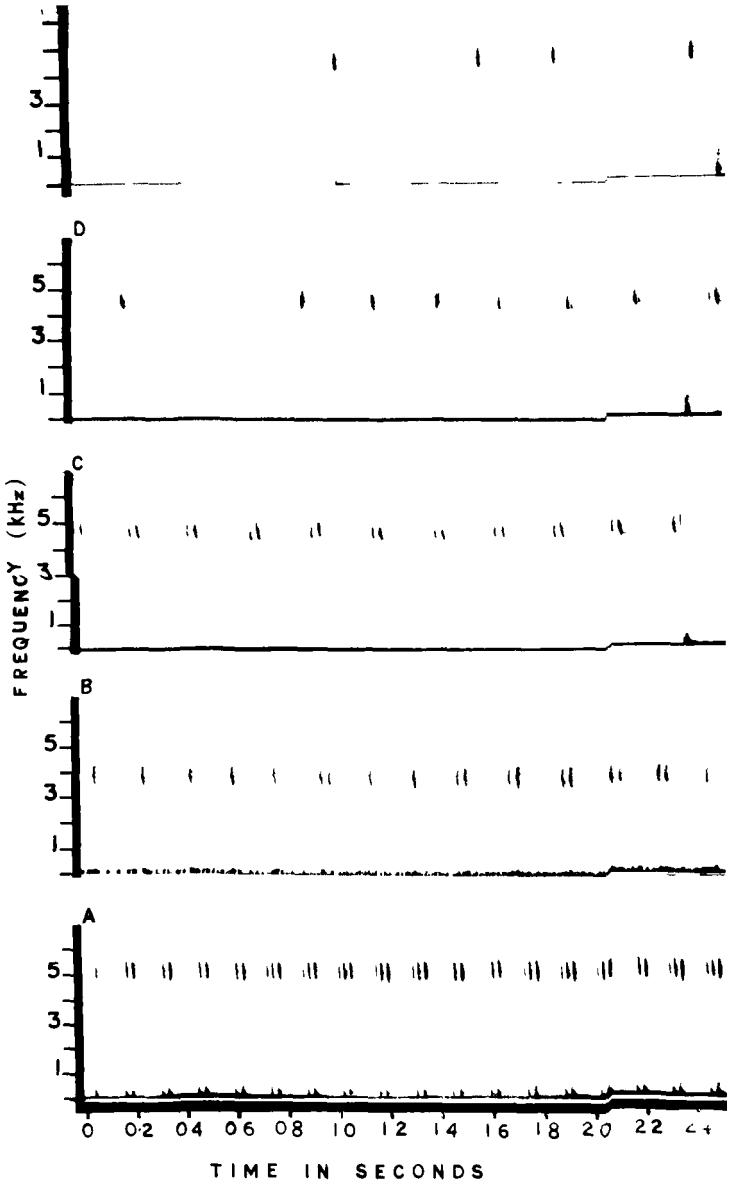
D
C
B
A
FREQUENCY (kHz)
5
3
1
0 0·2 0·4 0·6 0·8 1·0 1·2 1·4 1·6 1·8 2·0 2·2
TIME IN SECONDS

TABLE-8. Quantitative data on sexual behaviour of Gryllodes sigillatus under starvation with desiccation at 30 ± 1°C and 20 ± 5 per cent R.H.*

| rvation hours) | Average total duration (in seconds) ± S.E. Total Song | Total rest ♂ | Total rest ♀ | Total copulation | Number of Songs ♂ | Average total number of rests ± S.E. ♂ | Average total number of rests ± S.E. ♀ | Nu co ± |
|---|---|---|---|---|---|---|---|---|
| ) | 422.0±2.50 | 86.4±1.71 | 102.0±1.12 | 180.2±4.13 | 12.0±2.42 | 17.2±1.31 | 9.0±1.78 | 2.4± |
| 24 | 228.4±1.18 | 230.2±1.82 | 94.2±2.39 | 140.4± 7.21 | 3.0±2.21 | 23.4±1.31 | 25.2±1.67 | 1.2± |
| 8 | 121.2±3.02 | 350.6±1.22 | 271.4±1.42 | 121.0±4.39 | 7.4±1.71 | 28.2±1.28 | 12.4±2.32 | 2.2± |
| 2 | 25.8±2.53 | 395.8±1.47 | 390.2±1.21 | - | 3.0±1.82 | 17.0±1.27 | 20.0±1.98 | - |
| 5 | - | 568.4±1.38 | 420.4±1.02 | - | - | 9.0±1.21 | 4.2±1.72 | - |

* = Data based on 5 replicates of each observation

S.E.= Standard Error

LE-9. Quantitative data on sexual behaviour of Gryllodes sigillatus under starvation without desiccation at 30 ± 1°C and 80 ± 5 per cent R.H.*

| rvation | Average total duration (in seconds) ± S.E. | | | | Number of Songs ± S.E. | Average total number of rests ± S.E. | | Number copulat ± S.E. |
|---|---|---|---|---|---|---|---|---|
| urs) | Total song | Total rest ♂ | Total rest ♀ | Total copulation | | ♂ | ♀ | |
| 0 | 418.0±2.83 | 60.4±1.63 | 43.0±2.10 | 280.6±3.81 | 17.2±2.23 | 12.0±1.04 | 9.2±1.20 | 3.2± 0.0 |
| 4 | 367.4±2.61 | 185.2±1.22 | 170.6±1.83 | 279.8±17.66 | 11.0±3.01 | 20.4±2.81 | 12.0±1.20 | 2.2± 0.0 |
| 8 | 265.6±4.40 | 180.6±1.48 | 185.4±4.67 | 265.6±14.03 | 9.2±2.01 | 20.4±2.67 | 30.0±1.12 | 2.4± 0.1 |
| 2 | 207.2±1.99 | 295.0±1.17 | 296.2±3.24 | 180.0± 3.47 | 4.4±1.81 | 28.0±1.37 | 35.2±1.39 | 2.2± 0.0 |
| 6 | 8.2±1.22 | 365.2±1.92 | 288.2±4.28 | 93.4± 3.18 | 3.8±2.71 | 7.0±2.11 | 15.8±1.71 | 1.2± 0.0 |

* Data based on 5 replicates of each observation

S.E. Standard Error.

been recorded in table 8 and 9. From table (8), it is evident that at 30°C and 20 ± 5% R.H. the total duration of song is 422.0 ± 2.50 sec. 228.4 ± 1.18 seconds, 121.2 ± 3.02 seconds and 25.8 ± 2.53 seconds at 0 hr.,24 hrs.,48 hrs.,and 72 hrs. under starvation with desiccation. The resting (inactive) period of males is 86.4 ± 1.71 seconds, 230.2 ± 1.82 seconds, 350.6 ± 1.22 seconds, 395.8 ± 1.47 seconds and 568.4 ± 1.38 seconds at 0 hrs, 24 hrs, 48 hrs, 72 hrs, and 96 hrs. of starvation with desiccation respectively. Whereas the resting time in females is 102.0 ± 1.12 seconds, 94.2 ± 2.39 seconds, 271.4 ± 1.42 seconds, 390.2 ± 1.21 seconds and 420.4 ± 1.02 seconds at 0 hrs., 24 hrs. 72 hrs. and 96 hrs. of starvation with desiccation respectively. The total copulation period is 180.2 ± 4.13 seconds, 140.4 ± 7.21 seconds and 121.0 ± 4.39 seconds at 0 hr., 24 hrs. and 48 hrs. of starvation with desiccation respectively. After 48 hrs. of starvation with desiccation the pairs failed to copulate, the female tried to mount over the male but the male did not copulate at 72 hrs. and 96 hrs. The number of songs (groups of chirps) produced is 12.0 ± 2.42, 3.0 ± 2.21, 7.4 ± 1.71 and 3.0 ± 1.82 at 0 hr., 24 hrs. 48 hrs. and 72 hrs. of starvation with desiccation respectively but no song could be heard at 96 hrs. of starvation with desiccation. The total number of rest (between songs and active movements) of males is 17.2 ± 1.31, 23.4 ± 1.31, 28.2 ± 1.28, 17.0 ± 1.27

96 hrs. Whereas the average number of rests (between active movements) in case of females is 9.0 ± 1.78, 25.2 ± 1.67, 12.4 ± 2.32, 20.0 ± 1.98 and 4.2 ± 1.72 times at 0 hr., 24 hrs., 48 hrs., 72 hrs. and 96 hrs. of starvation with desiccation respectively. The number of copulation is 2.4 ± 0.01, 1.2 ± 0.12 and 2.20 ± 0.03 at 0 hr., 24 hrs. and 48 hrs., of starvation with desiccation respectively. At 72 hrs. and 96 hrs. they did not copulate.

From the Table (9), it is apparent that the total duration of courtship song under the condition of starvation without desiccation is 418.0 ± 2.83 seconds, 367.4 ± 2.61 seconds, 265.6 ± 4.40 seconds, 207.2 ± 1.99 seconds and 8.2 ± 1.22 seconds at 0 hr., 24 hrs., 48 hrs, 72 hrs., and 96 hrs. respectively. The average total resting period in case of males is 60.4 ± 1.63 seconds, 185.2 ± 1.22 seconds, 180.6 ± 1.48 seconds, 295.0 ± 1.17 seconds, and 365. 2 ± 1.92 seconds at 0hr., 24 hrs, 48 hrs., 72 hrs. and 96 hrs., of starvation with desiccation respectively. Whereas the average resting period of females is 43.0 ± 2.10 seconds, 170.6 ± 1.83 seconds, 185.4 ± 4.67 seconds, 296.2 ± 3.24 seconds and 288.2 ± 4.28 seconds at 0 hr., 24 hrs., 48 hrs., 72 hrs. and 96 hrs, of starvation without desiccation respectively. The average total copulation period varied as 280.6 ± 3.81 seconds, 279.8 ± 17.66 seconds, 265.6 ± 14.03 seconds, 180.0 ± 3.47 seconds, and 93.4 ± 3.18

seconds at 0 hr., 24 hrs., 48 hrs., 72 hrs., and 96 hrs., of starvation without desiccation respectively. The average number of songs (groups of chirps) produced by males is 17.2 ± 2.23, 11.0 ± 3.01, 9.2 ± 2.01, 4.4 ± 1.81 and 3.8 ± 2.71 at 0 hr., 24 hrs., 48 hrs., 72 hrs., and 96 hrs. of starvation without desiccation respectively. The number of rest (between songs) of males varied as 12.0 ± 1.04, 20.4 ± 2.81, 20.4 ± 2.67, 28.0 ± 1.37 and 17.0 ± 2.11 while it is 9.2 ± 1.20, 12.0 ± 1.20, 30.0 ± 1.12, 35.2 ± 1.39 and 15.8 ± 1.71 in females at 0 hr, 24 hrs., 48 hrs., 72 hrs. and 96 hrs. of starvation without desiccation respectively. The number of copulations has been observed 3.2 ± 0.02 at 0 hr., 2.2 ± 0.03 at 24 hrs., 2.4 ± 0.12 at 48 hrs., 2.2 ± 0.02 at 72 hrs. and 1.2 ± 0.03 at 96 hrs. of starvation without desiccation. It has been observed that male of Gryllodes sigillatus started singing courtship rhythms in the presence of female. The courtship song is not a continuous one but may be heard having many gaps varying from 2 seconds to 60 seconds. While singing, the male tried to come closer to the female. In response to this sometimes the female moved few cm. towards the male and sometimes became motionless and standstill. As the male came closer to the female its antennae moved and touched the antennae of female, The female also moved its antennae. In the advanced courtship, the male

male produced few chirps. Finally the male flattened its body to the substratum and the female mounted over the male. Two to four minutes are taken by the pair to adjust themselves in this posture. The mounting lasts for 2-5 minutes. After separation of the sexes, the spermatic fluid covered with a glandular secretion (spermatophore) remains attached with the base of the ovipositor. Females are seen to consume the spermatophore under the normal condition as well as under the starvation. The males also consume it in rare cases.

# CHAPTER - V

## D I S C U S S I O N

## D I S C U S S I O N

The total effect of starvation on the various instars of *Gryllodes sigillatus* is marked by a decrease in the body weight of the individuals. It was found that the loss of body weight is variable with respect to time of starvation and in the individuals of the same age as well as those of different ages under the conditions of starvation (Tables 1 and 3). Despite the individual variability it appears that there exists a certain order in the changing of body weight of individuals. Under conditions of starvation with desiccation the life span of the individual instars is shorter as a result the pattern of change in body weight is not as distinct as in individuals subjected to starvation without desiccation (Appendix Figs.1-16). Apart from this, on the basis of this change in weight the total starvation period can be divided into 3 phases. In the first phase under conditions of starvation with or without desiccation the loss in weight is found to be rapid as compared with the middle phase. During this second phase the conditions seem to be a bit stabilized, followed by a further loss in weight, though less rapid than the first phase culminating in the death of the individual marking the end of the third. In the above experiments when the instars were subjected to such adverse environmental factors as starvation and desiccation it is reasonable to assume that the living organisms will react to such conditions in a way so as to avoid sudden death as far

as possible. In such an eventuality the built-in defence mechanism of the organism is known to come into operation with varying modes and degrees of expression depending largely upon the nature of the stimulus. These reactions may be either of the nature of avoiding reaction or adaptive reaction expressed in term of change in the metabolic rate so as to reduce rate of katabolism. Under the present conditions the individual instars seem to modify their metabolism to counteract the adverse environmental factors, whence the sudden loss of weight in the beginning followed by a period of adjustments during which there is slight fluctuation. Afterwards when this mechanism collapses there is once again a sudden loss of weight followed by death. Baud (1973) made similar observations in the caterpillars of Bombyx mori L. He found that under starvation a stage of equilibrium is set up between degeneration and recovery followed by a stage of irrevocability, afterwards death occurs.

Regarding the mean rate of loss in weight ( Tables 1 and 3) during the life time of a single individual it may be pointed out that this mean rate of loss has been expressed in terms of percentage of the initial body weight per day. In first instar nymphs the mean rate of loss of weight is highest in both the conditions of starvation, slightly tending to increase in the second instar under conditions of starvation

without desiccation. Further the rate of loss of weight decreases with the advancing age of the nymphs. In the subsequent instars the mean rate of loss in weight is always higher under starvation with desiccation than under starvation without desiccation. There are, however, certain exceptions in instars-tenth, eleventh and twelfth male (Fig.2). In tenth, eleventh and twelfth male instar nymphs, the rate of loss of weight is less under starvation with desiccation conditions as compared to their counterparts under starvation without desiccation. It may also be noted that sexes at twelfth instar stage can be externally distinguished, the preparation for which must have started some times earlier. It is intriguing as to how this variation can be accounted for. May it be that the rate of loss under desiccation conditions might have been exceptionally low or vice versa in conditions of without desiccation, it might have been abnormally high as is evident from graph in Fig.2. Gunn (1935) observed that in desiccation experiments the rate of loss of weight expressed as percentage of the initial weight was double in larger species of Periplaneta americana as compared with the smaller one Blatella germanica . In his experiment the size of the individual has been taken as a single factor. Observations of the present writer on the developing instars of Gryllodes sigillatus are not in agreement with those of Gunn. Because in the first place he subjected adults of different

species to desiccation whereas in the present experiments mostly immature stages have been taken and those of one species only. Secondly, the first three instars in Gryllodes sigillatus are not only much smaller but soft bodied too as a result of which the rate of loss in weight in them is much higher than that of older instars. Noble-Nesbitt (1964) found that during starvation the insect loses dry matter to the extent of 1.4% of the initial weight per day and 2.1% during desiccation, which means that the rate of loss of weight is greater under desiccation condition than under starvation. These observations are in partial agreement with the present author.

After the sexes differentiate, the females show a progressive decrease in the rate of loss of weight (per cent of the initial weight) under starvation with desiccation while loss in weight is much less in females under starvation without desiccation. The males of twelfth instar nymphs on the other hand show initially some increase and later on gradual decrease in rate of loss of weight under starvation with desiccation condition. The males under starvation without desiccation behave more or less the same way as the females under identical condition (Fig.2).

The water content left in the Gryllodes sigillatus under starvation with disiccation varies from instar to instar. In instar nymphs from first to seventh, the water content increases

gradually with the increase of age. The increase in the water content may be due to taking of much amount of water along with food and less loss of water during starvation with desiccation with the increasing age. The resistance to desication may also be due to the development of the cuticle which is thinest in case of first instar nymphs and it hardens progressively in the succeeding instars. Manton and Ramsay (1937) have stated that all the terrestrial animals have to solve the problem of desiccation by developing a water proofing external body surface and the reduction of loss of water by faecal matter. In Gryllodes sigillatus the effects of desiccation are more pronounced in the younger instars nymphs than the older ones. It has been observed in the first to seventh instar nymphs the loss in body weight decreases with the increase in age. In eighth, ninth, tenth and eleventh instar nymphs the water content retained in the body is less than the previous group. The loss in body weight is also less in these instars than the previous ones except in eighth instar nymphs. In this group the resistance to desiccation increases but the water content is not very much affected and is more or less identical. In the male instar nymphs under this condition the water content gradually increases except in males of twelfth instar nymphs where it is slightly more than the succeeding instars. A progressive increase may also be observed in the loss of body weight in all the male instar nymphs except in males of thirteenth instar nymphs. In case of females

progressive increase except in fifteenth instar nymphs. The survival time of fifteenth female instar nymphs is more than the female nymphs of other instars. So there is more loss in the body weight and the water content is less than the females of fourteenth instar nymphs. It seems that the resistance to desiccation increases with the increase in age of the female instar nymphs. The water content in female instar nymphs is greater than the water content of the male instar nymphs under this condition.

The water content left in the body after starvation till death under starvation without desiccation varies from instar to instar. From first to third instar nymphs the water content progressively decreases. It increases from fourth to seventh instar nymphs. Similar pattern may be observed in the loss of body weight in these instar nymphs. Survival of first and second instar nymphs is adversely affected by starvation without desiccation while the third to seventh instar nymphs survived longer. Starvation can affect slightly the water content of the body because it is lost in the repiratory processes and excreted in faecal matter. The water content of the body from eighth to eleventh instar nymphs is variable. This variability may be due to the variability in the survival time. The water content is slightly more where the loss in weight of body is less. It may be concluded that water content is slightly affected even in

the starvation without desiccation. In male instar nymphs under this condition there is an increase in water content left in the body after starvation without desiccation except in sixteenth instar nymphs. It may be concluded that the resistance to starvation without desiccation increases in male instar nymphs with the increasing age. In case of female instar nymphs the water content increases with the increase in age. In fifteenth and sixteenth instar female nymphs the water content is the same. The females of the respective instars live longer than the males under this condition.

Comparative study shows that in first, second, fifth, seventh, eighth, twelfth females, thirteenth females, fourteenth males, fifteenth males and females and sixteenth male instar nymphs, the water content is greater under the condition of starvation without desiccation than in their counterparts under the condition of starvation with desiccation. The period of starvation till death of instars is longer under starvation without desiccation than under starvation with desiccation. It seems that the instar nymphs took some water from some source. It may be possible that these instar nymphs took water from subsaturated atmosphere ( 80±5 per cent R.H.) under starvation without desiccated conditions. It is probable and may happen as reported by Okasha (1972) in Thermobia that the percentage of water content is increased due to starvation. Edney (1957) and

Noble-Nesbitt (1969) also established that few arthropods can take up water from subsaturated atmosphere. In third, ninth, tenth, eleventh, twelfth male, thirteenth male, fourteenth female and sixteenth female instar nymphs the water content was found greater under the condition of starvation with desiccation than under the condition of starvation without desiccation. In fourth and sixth instar nymphs the water content is identical in both the conditions of starvation. Similar observation has been made by Aziz (1960) in fourth instar hoppers of Schistocerca gregaria Forsk. According to him the loss in weight after starvation is greater under low humidity ( 30 per cent ) than under high humidity ( 90 per cent) while the water content was identical in both the groups of instars. He has made observations with the same duration of starvation in low and high R.H. But here the time of observations varies considerably as the observations have been made till the death of the nymphs.

The sexual behaviour of Gryllodes sigillatus has two stages: (i) Preliminaries performed in respect of relative positions of male and female and production of courtship song by male. The male comes nearer the female in reverse position with the posterior end facing the female head and sometimes the male and female may come to stay side by side with heads facing opposite directions. The male now produces distinctive sound and touches the female head by its posterior portion of the body.

(11) Advanced courtship which is of very short duration in Gryllodes sigillatus lasting 2-3 minutes. The female starts mounting over the male for copulation. The above two stages are behaviourally very distinct. Since the insect activities progressively decrease under conditions of starvation with and without desiccation (Tables 8 and 9) the song becomes feeble and irregular as the starvation prolongs but these effects are very much conspicious under starvation with desiccation (Fig.3 and 4). The length of the duration of the song diminishes particularly under the conditions of starvation with desiccation than under starvation without desiccation. The males fail to produce any courtship song after 72 hrs. of starvation with desiccation whereas under starvation without desiccation males continue to produce courtship rhythms upto 96 hrs. of starvation. The chirp rate is 5 per second under starvation with desiccation but it varies from 2-7 per second under starvation without desiccation ( Figs. 3 and 4). The chirps contain 1-3 pulses in both the conditions. One pulse is produced in 10-20 milli seconds. The frequency of the courtship song varies from 4.3 k Hz to 5.1 k Hz under starvation with desiccation whereas it varies from 4.0 to 5.2 kHz under starvation without desiccation (Figs.5 and 6). In other Gryllodes for instance in Nemobius fasciatus the male produces 8-12 chirps per second having 2-5 pulses per chirp (Alexander and Thomas, 1959). In Achata 5-6 pulses per

second were observed by Alexander (1957), while the pulse rate in Nemobius tinutus was found to be 2-3 pulses per second grouped in 2-4 in a set. Female sound orientation depends upon the rhythmic organisation of the courtship song, it is the chirp which determines the strength of reaction i.e., the movement of female towards the sound source (Shuvalov and Popov, 1973). Due to the decreasing quantity of the courtship song, the reaction of the female is decreased. Similar observations have been made in Gryllodes sigillatus. It has been observed during these experiments that due to starvation inactiveness increases as is clear from the variations in the duration of song, time of copulation and period of passive rest (inactiveness) under both the conditions but are more pronounced under starvation with desiccation (Tables 8 and 9). Continued starvation in all probability leads to energy crisis within the body of the individual which has a direct bearing on the activities of the body in general and those associated with sexual behaviour in particular. Under conditions of starvation with desiccation the effects are more pronounced and adverse due to desiccation which causes dehydration in the body fluids and it becomes tough to get energy even from the reserve food than under starvation without desiccation condition.

From these data it can be concluded that apart from starvation being a common factor, desiccation has very adverse effects on the sexual behaviour of Gryllodes sigillatus due to dehydration accompanying starvation.

CHAPTER - VI

# S U M M A R Y

# S U M M A R Y

*Gryllodes sigillatus* Walker is a household pest found in dark places, kitchens, cupboards and paper baskets, etc. It feeds upon starchy food, papers, clothes, vegetables, breads, etc. Effects of starvation have been studied in all the instar nymphs under desiccation ( 30 ± 1°C and 20 ± 5% R.H.) and without desiccation ( 30 ± 1°C and 80 ± 5% R.H. ) upon weight, water content and also the sexual behaviour of adults. The results are summarized below:-

1. Due to starvation loss in body weight occurs in all the instars from first to sixteenth. Initial stages are more susceptible to starvation with and without desiccation as compared with the older stages. The resistance to weight loss increases in general with age under starvation with and without desiccation.

2. The loss of body weight is highest in the first instar than in the higher instar nymphs under both the conditions.

3. Rate of loss of weight as percentage of the initial weight is higher in all instar nymphs, except in tenth, eleventh and males of twelfth instar under starvation with desiccation than under starvation without desiccation condition. In general the rate of loss of weight as percentage of the initial weight decreases with the increase in age under both the conditions.

4. There is a definite pattern of the loss of body weight in all the instar nymphs having 3 phases, not very distinct under starvation with desiccation, as compared with starvation without desiccation.

5. In first instar nymphs the mean rate of loss of weight per day is highest in both the conditions of starvation slightly tending to increase in the second instar nymphs under starvation without desiccation.

6. In females there is a progressive decrease (from twelfth to sixteenth instar nymphs) in the rate of loss of weight per day under starvation with desiccation while it is less in females under starvation without desiccation.

7. The males under starvation without desiccation behave more or less the same way as the females under similar conditions.

8. There is a marked difference in the rate of loss of weight per day due to starvation with desiccation and without desiccation in all the instars, except in tenth, eleventh and males of twelfth instar nymphs.

9. The maximum effect of desiccation may be observed in seventh and eighth instar nymphs.

10. In both the sexes the effects of starvation with and without desiccation are different. The longevity of females under starvation without desiccation is more than the males.

But it is more in males under starvation with desiccation except in fourteenth and fifteenth instars where females survived longer than males.

11. Autocannibalism is present under starvation without desiccation while it is absent under starvation with desiccation in seventh instar nymphs and onwards till sixteenth instar nymphs. Both sexes show autocannibalism.

12. The water content of the body of instar nymphs has been studied after death under starvation with and without desiccation. The water content of the body varies from instar to instar under starvation with and without desiccation.

13. The percentage water content of the body after death is identical in fourth and sixth instar nymphs under the conditions of starvation with desiccation and without desiccation.

14. In third, ninth, tenth, eleventh, twelfth males, thirteenth males, fourteenth females and sixteenth instar female nymphs, the water content of the body is greater under starvation with desiccation than in their counterparts under starvation without desiccation.

15. In the remaining group of instar nymphs -first, second, fifth, seventh, eighth, twelfth females, thirteenth females, fourteenth males, fifteenth males and females and sixteenth

instar male nymphs the percentage water content is higher in the body under the conditions of starvation without desiccation than in their counterparts under starvation with desiccation. Probably water uptake mechanism is present.

16. The sexual behaviour of Gryllodes sigillatus has two stages- (i) preliminaries performed by the male and production of courtship song and (ii) advanced courtship in which the female mounts over the male. These two stages are present under starvation with and without desiccation but the activities (movements, duration of song and time of copulation) progressively decrease under both the conditions of starvation. The effects are more adverse under starvation with desiccation.

17. Males produce song by terminal stridulation. The courtship song becomes feeble and irregular as the starvation prolongs; effects are more conspicuous under starvation with desiccation than under starvation without desiccation.

18. Under starvation with desiccation the male fails to produce audible song after 72 hours and the pair fails to copulate after 48 hours. Whereas under the conditions of starvation without desiccation song and copulation are present upto 96 hours of starvation also.

19. Number of rests (gaps between activities) increases in general in both males and females with the prolongation of starvation under both the conditions of starvation with and without desiccation. The total resting period increases in both males and females. The increase in rest (inactiveness) is more pronounced under starvation with desiccation than under starvation without desiccation.

20. The females are more active than males in both the conditions of starvation with and without desiccation.

21. The average total duration of song varies from 422.0± 2.50 seconds to 25.8±2.53 seconds under starvation with desiccation while it varies from 418.0 ± 2.83 seconds to 8.2±1.22 seconds under starvation without desiccation.

22. The chirp rate of the courtship song is 5 chirps/second under starvation with desiccation and 2-7 chirps/second under starvation without desiccation.

23. The intensity of the chirps decreases as the starvation with desiccation prolongs while it is unaffected under starvation without desiccation.

24. The courtship song has 1-3 pulses in each chirp. The pulse rate is 8-10 pulses/second under starvation with desiccation and 3-30 pulses/second under starvation

without desiccation. One pulse is produced in 10 - 20 milliseconds under both the conditions.

25. The frequency of the courtship song varies from 4.13 to 5.1 kHz under starvation with desiccation and from 4.0 to 5.2 kHz under starvation without desiccation.

# REFERENCES

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Aheran, G.A., 1970, The Control of water loss in desert Tenebroinid beetles. J.exp. Biol., 53:573-595.

Ahmad, D., 1965, Bionomics and control of Gryllodes sigillatus Walker. Ph.D. dissertation, The Aligarh Muslim University, Aligarh.

Alexander, R.D. 1957, Sound production and associated behaviour in insects. Ohio. Jour. Sci. 57:101-113,13 figs.

Alexander, R.D.,1960, Sound communication in Orthoptera and Cicadidae. Animal Sounds (Lanyon and Tavolga,ed.) The American Institute of Biological Sciences,7,38.

Alexander,R.D., 1967, Acoustic communication in Arthropods. Annu. Rev. Entomol, 12: 295-526.

Alexander, R.D., 1975, Natural selection and specified chorusing behaviour in acoustical insects. In Insects, science and society. Edited by D. Pimentel. Academic Press. New York,pp. 35-37.

Alexander, R.D.,1976, Acoustic communication in arthropods. Annu Rev. Ent., 12: 495-526.

Alexander, R.D. and Thomas, E.S. 1959, Systematic and behavioral studies on the crickets of Nemobius fasciatus

Alexander, R.D. and Moral, G.H. 1967, Seasonal and daily chirping cycles in the northern spring and fall fied crickets. Gryllus veletis and Gr pennsylvanicus. Ohio. J. Sci., 67: 200-209, 6 figs.

Allard, H.A. 1912, Variation in the stridulation of Orthoptera. Ent. News, 23: 460-462.

Allard, H.A. 1917, Synchronism and synchronic rhythm in the behaviour of certain creatures. Amer. Nat.,51: 438-446.

Allard, H.A. 1930, Changing the chirp rate of the snowy tree cricket Oecanthus niveus with air current. Science, 72: 347-349.

Allard, H.A. 1957, The stridulation of some crickets in the Dominican Republic. J. Wash. Acad. Sci.,47:150-152.

Arbogast, R.T. and Carthon, M. 1972, Effects of starvation and desiccation on the water balance and humidity response of adults Oryzaephilus surinamensis (Coleoptera: Cucujidae ) . Entomol. Exp. Appl., 15(4): 488-498.

Azis, S.A. 1957, The reaction of the desert locust, Schistocerca gregaria Forsk. to physical factors with special reference to relative humidity. Bull.ent.Res.,48(3):

Azim, S.A. 1960, Effects of starvation and preconditioning on the water content and loss in weight of fourth instar hoppers of the desert locust, Schistocerca gregaria Forsk. (Orth: Acrididae ). Ind. J. Ent., 22 (2) : 109-111.

Aziz, S.A. 1961, Relation between starvation and activities of first instar hoppers of the desert locust, Schistocerca gregaria Forsk. (Orth: Acrididae ). Proc. zool. Soc., 14 (2) : 143- 149.

Aziz, S.A. 1973, Relation between starvation and activities of fourth-instar hoppers of the desert locust, Schistocerca gregaria Forsk. (Orth: Acrididae). Proc. zool. Soc., Calcutta, 26 :107-112.

Banerjee, S.K., Singh, K.M. and Bose, K.C. 1977, Effects of starvation and pyrethrum treatment of cation concentration in nerve tissue of desert locust, Schistocerca gregaria Forsk. Ind. J.Ent., 39(2): 101-106.

Band, L. 1973, Contribution to the physiological study of starvation in an insect: the larvae of Bombyx mori L. (Lep: Bombycidae). Ann. Zool. Econ.Anim., 5(2):187-20(

Beament, J.W.L. 1964, The active transport and passive movement of water in insects. Adv. Insect Physiol., 2: 67-129.

Beant, J.W.L., Noble-Nesbitt, J. and Watson, J.A.L. 1964, The water proofing mechanism of Arthropods. III. Cuticular permeability in the firebrat, Thermobia domestica (Packard). J.exp. Biol., 41: 323-330.

Bessey, C.A. and Bessey, E.A. 1898, further notes on thermometer cricket, Amer. Nat., 32 : 263-264.

Bigelow, R.S. 1962, factors effecting developmental rates and diapause in field cricket. Evotution, 16: 395-406.*

Brannen, J.P. 1975, A population model for dermestid beetle survival under starvation and cannibalism. J. Theor. Biol., 49(1): 179-189.

Brooks, M. 1881, Influence of temperature on the chirp of cricket. Pop. Sci. Monthly, 20: 268.

Browning, T.O. 1953, The influence of temperature and moisture on the uptake and loss of water in the egg of Gryllus commodus Walker (Orth: Gryllidae). J. exp. Biol., 30: 104-115.

Bunting, W. 1955, Some notes on Acheta domesticus L. (Orth: Gryllidae). Ent. Month. Mag., London. 91: 138-140.*

Bursell, E. 1964, Environmental aspacts. temperature. In M. Rockstein (ed.). The physiology of Insecta. I, 283-321. New York: Academic Press.

Buswine, J.R. 1955, Simple method for rearing the cricket ( Gryllus domesticus ) L. with some observations on the speed of development at different temperatures. Proc. R. ent. Soc. Lond., (A) 30: 15-18. *

Buxton, P.A. 1930, Evaporation from the meal-warm (Tenebrio: Coleoptera ) and atmospheric humidity. Proc. R. Soc., B. 106:560-577.

Buxton, P.A. 1932, Terrestrialinsects and the humidity of the environment. Biol. Rev. 7: 275-317.

Chu, H.F. & Wang, L.Y. 1951. Life history of the field cricket Gryllus testaceus and its control. Ann. Ent. Sisini, Peking. 1:291-307. 22 figs. *

Cloudsley-Thompson, J.L. 1964. Terrestrial animals in dry heat: arthropods. In D.B. Dill, E.F. Adolph and C.G. Wilber (eds.) "Handbook of Physiology", Section 4, pp.451-465. American Physiological Society,

David, N.A . 1976. Interspecific differences in frequency and other physical parameters of pair-forming sounds of bush katydids (Orth: Jettigoniidae: Phaneropteriae). Ann. Entomol. Soc. Amer., 69: 1135-1144.

Dolbear, A.E. 1897. The cricket as a thermometer. Amer.Nat. 31: 970-971.

Dumortier, B. 1963. The physical characteristics of sound emissions in Arthoptera. In Acoustic Behaviour of Animals. Elsevier Publ. Co. Amsterdam. 633p.

Edes, R.T. 1899. Relation of the chirping of the tree cricket (Oecanthus niveus) to temperature. Amer. Nat., 33: 935-938.

Edney, E.B. 1957. The water relations of the Arthropods. Cambridge University Press. 109 P.

Edney, E.B. 1967. Water relation in desert arthropods. Science N.Y. 156: 1059-1066.

Frings, H.and Frings, M., 1957, The effects of temperature on chirp rate of male cone-headed grass hopper, Neoconocephalus ensiger. J.exp.Zool., 134: 411-426.

Gunn, D.L. 1933. The temperature and humidity relations of the cockroach (Blatta orientalis). 1. Desiccation. J. exp. Biol. 10 : 274-285.

Gunn, D.L. 1935. The temperature and humidity relations of the cockroach. 111. A comparision of temperature preference, and rate of desiccation and respiration of Periplaneta americana, Blatta Orientalis and Blatella germanica. J. exp. Biol., 12: 185-190

Hallenbeck, C. 1949. Insect thermometer, Nat. Hist. (New York), 58: 256-259.

Haskell, P.T. 1964. Sound production. The Physiology of Insecta. M. Rockstein (ed.) Academic Press. pp. 563-608.

Hill, K.G. and Boyan, G.S. 1977. Sensitivity to frequency and direction of sound in the auditory system of cricket (Orth: Gryllidae). J. Comp. physiol ., 121(1):79-97.

Hill, K.G., Loftus- Hills, JJ. and Cartside, D.F. 1972. Premating isolation between the Australian field crickets, Teleogryllus commodus and T. oceanicus Austral. J. Zoal, 20: 153-163.

Hoy, R.P. and Pant, R.C. 1973. Genetic control of song specificity in crickets Science, 180: 82-83.

Hill, L. and Goldsworthy, G.F. 1970. The utilization of reserves during starvation of larvae of migratory locust. Comp. Biochem. Physical., 36(1):61-70.

Ibrahim, M.M. 1973. Survival of starved Ailoous thalassinus F. (Orth: Acvididae) Zangnas Entomal., 73 (4): 337-340.

King, P.E. and Hopkins, C.R. 1963. Length of life of the sexes in Nasonia vitripennis (Walker) (Hymenoptera: Pteromalidae) under conditions of starvation. J. exp. Biol., 40: 751-761.

Keeton, W. 1967. Biological Science N.Y: W.W. Norton and Co. 955 p.p.

Kennedy, J.S. 1937. The humidity relations of the African migratory locust focuata migratoria migratorioidea R. and F. gregarious J. exp. Biol. 14: 187-197. *

Lindsay, E. 1940. The biology of siver fish Catenolepisma longicaudata Esch., with particular reference to feeding habits. Proc. Roy. Soc. Vict., 52 : 35-83.

Madsen, C. Vickery, V.C. and Nowosielski, J. 1970 Variation in song patterns of Antipodean Teleogryllus species (Orth: Gryllidae) and a proposed phonetic classification. Can. J. Zool., 48: 797-801.

Manton, S.M. and Ramsay, J.A. 1937. Studies on the Onychopora. III. The control of water loss in Peripatopsis. J. exp. Biol., 14: 470-472.

Marler, P. and Hamilton, W. 1967. Mechanisms of Animal Behaviour N.Y.: J. Wiley and Sons, Inc. 77 pp.

Mellanby, K. 1934. The influence of starvation on thermal death point of insects. J. exp. Biol, 11: 48-53.

Mellanby, K. 1935. The evaporation of water from insects. Biol. Rev., 10: 317- 333.

Minoransky, V.A. 1966. Observation on the crickets Gryllus desertus Pall. in Roster region. Zool. Zh., 45: 383-389. *

Morrill, W.L. and Greene, G.L. 1973. Distribution of fall armyworm larvae (Spodoptera frugiperda: Lep., Noctuidae). 2. Influence of biology and behaviour of larvae on selection of feeding sites. Environ. Entomol., 2(3): 415-418.

Noble- Nesbitt, J. 1969. Water balance in the firebrat, Thermobia

Noble-Nesbitt,J.1970. Water balance in the firebret,Thermobia domestica (Packard). The site of exchange of water from atmosphere. J. exp. Biol., 52: 193-200

Ohmachi,FQ and Matsumura, I. 1953. Observations and experiments on four types in life history of Gryllodea. Oyo-Dobuts. Zasshi Tokyo.16: 104-110. *

Okasha, A.Y.K. 1971. Water relations in an insect, Thermobia domestica.I. Water uptake from sub-saturated atmosphere as an means of volume regulation. J.exp. Biol., 55: 435 448.

Okasha, A.Y.K. 1972, Water relations in an insect, Thermobia domestica. II. Relationship between water content, water uptake from subsaturated atmosphere and water loss. J. exp. Biol. 57: 285-296.

Paton, J.A.; Capranica, R.R.; Dragaten,P.R. and Webb,W.W. 1977. Physical basis for auditory frequency analysis in field crickets (Orth: Gryllidae). J. Comp.Physiol., 119(3): 221- 240.

Paul, R.C. 1976. Acoustic response to chemical stimuli in ground crickets ( Orth., Gryllidae, Nemobiinae) Nature, 263 (5576): 404-405

Paul, R.C. 1977. Species specific phonotaxis in Gryllus females (Orth: Gryllidae). Fla. Entomol. 60(1): 67-68.

Pierce, G.W. 1948. The songs of insects. Harvard University Press. (pp.195-198).

Popov., A.V. 1975. Acoustic behaviour and migration of Gryllus campestris. (Orth: Gryllidae). Zool. Zh., 45(12): 1809.

Popov, A.V. and Shuvalov, V.F. 1974. Spectrum intensity and directional characteristics of calling-song emission in Gryllus campestris under natural conditions. (Orth: Gryllidae) Zh. Evol. Biokhim. Fiziol., 10(1): 72-80.

Popov, A.V.; Shuvalov, V.F.; Kuyazev, A.N. and Klap- Spasovska-ya N.A. 1974. The communication sound signals of Gryllidae (S. lato) (Orth.) of South-West Tadzhikistan (USSR). Entomol. Oboar., 53(2): 258-279.

Ramsay, J.A. 1935. The evaporation of water from the cockroach. J.exp. Biol., 12: 373-383.

Rastogi, S.C. and Lohia, N.K., 1972. Histochemical studies on the midgut and hepatic caeca of Periplaneta americana (L). Z. MIKROSK- Anat FORSCH (LEIPZ)., 86(4): 496-502.

Rence, B., and Loher, W. 1977. Contact chemoreceptive sex recognition in male cricket Teleogryllus commodus (Orth: Gryllidae). Physiol. Entomol., 2 (3): 225-236.

Rheinlaender, J.; Kalmring, K.; Popov, A.V. and Rehbein, H.1976. Brain projections and information processing of biologically significant sounds by two large ventral cord neurons of Gryllus bimaculatus De Geer.(Orth: Gryllidae). J. Comp. Physiol.,110(3) 251-269

Rinterknecht, Elisabeth, Parte, A. and Joly,P. 1972. Ultrastructural modifications in the oenocytes under the effects of starvation in Locusta migratoria. CR Hebd. Seances Acad. Sci. Ser D. Sci. Nat. 275(10): 1063-1066.

Roshkova, G.I. and Polishchuk, N.A. 1976. Constant representation of signal source location in the cercal system of cricket. Biofizika, 21(1): 144-149.

Shelford, V.E. 1914. The importance of the measure of evaporation in economic studies of insects. Journ. Econ.Ent.,7 : 229-233.

Shull, A.F. 1907. The stridulation of the snowy tree-cricket (Oecanthus niveus ). Canad. Ent., 39: 213- 225.

Shuvalov, V.F. and Popov, A.V. 1973. The importance of the rhythmic organization of the calling-song of male Gryllus for sound orientation in the females (Orth: Gryllidae). Zool. Zh., 52(8), 1185.

Ulagaraj, S.M. 1975. Mole crickets: Ecology, behaviour and dispersal flight (Orth: Gryllotalpidae: Scapteriscus). Environ. Entomol., 4 : 265- 273.

Ulagaraj, S.M. and Walker, T.J. 1973. Phonotaxis of crickets in flight: Attaraction of male and female crickets to male calling song. Science, 182: 1278- 1279.

Ullagaraj, S.M. and Walker, T.J. 1975. Response of flying mole crickets to three paramters of synthetic songs broadcast outdoor. Nature, 253: 530-532,

Urarov, B.P. 1931. Insects and climate. Trans. R. ent. Soc. Lond., 79 : 1- 247.

Veselovsky, Jan, and Skrobak, J. 1972. Changes in the levels of free amino acids in muscles of the field cricket Gryllus campestris L. under extreme conditions of starvation. Biologia (Bratislava),

Waker, T.J. 1957. Specificity in the response of female tree crickets (Orth: Gryllidae: Oecanthinae) Ann. Entomol Soc.Amer., 50: 626-636.

Walker, T.J. 1962. Factors responsible for intraspecific variation in calling songs of crickets. Evolution, 16: 407-428.

Walker, T.J. 1964. Cryptic species among sound producing ensiferan Orthoptera. Quart. Rev. Biol. 39 345-355.

Walker, T.J. 1969. Systematics and acoustic behaviour of United States cricketsof the genus Oracharia (Orth: Gryllidae). Ann. Entomol. Soc. Amer,62(4)

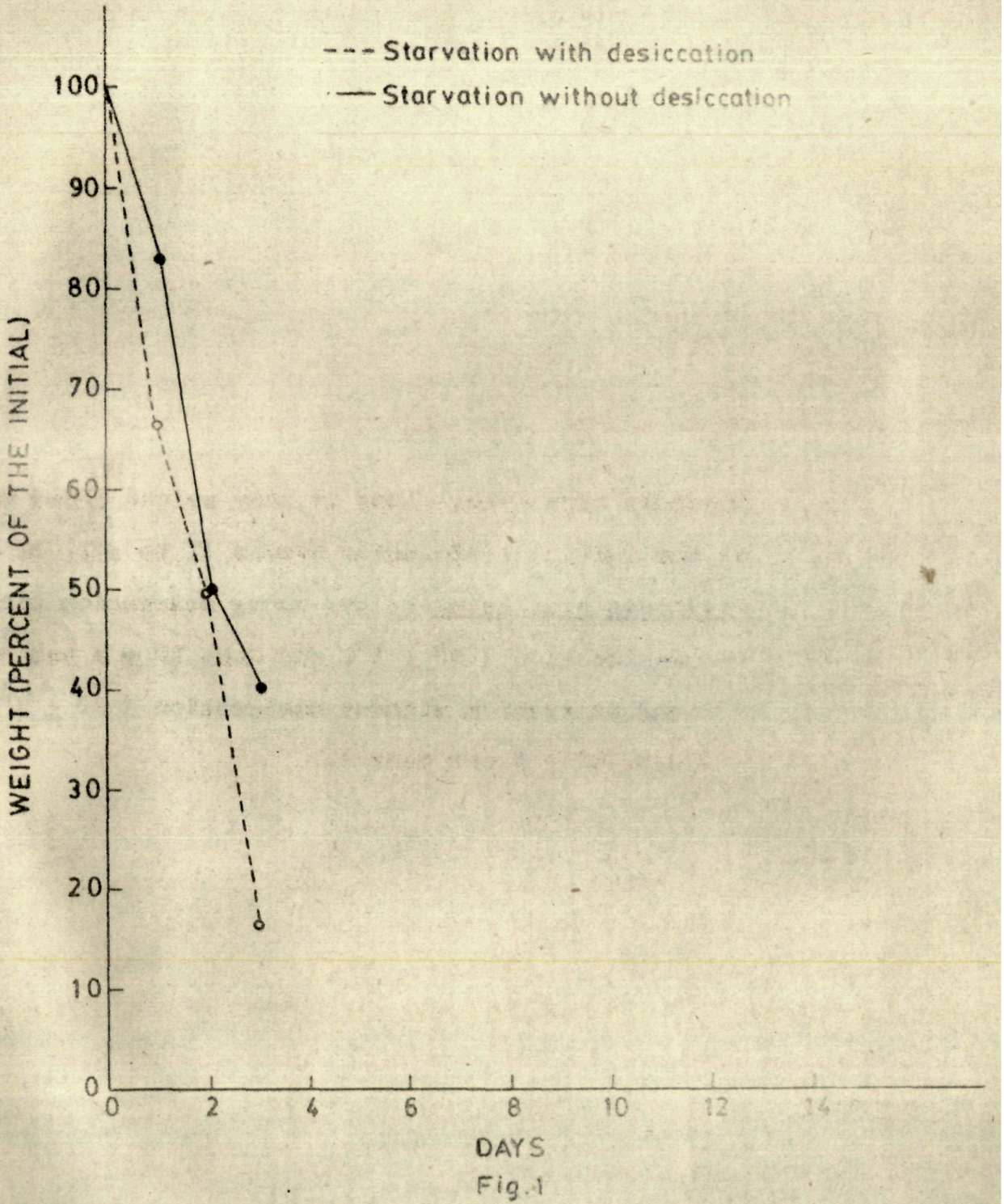
Wigglesworth, V.B. 1965. "The principles of Insect physiology" London; Methuen Press 741 pp.

Wills, E.R. and Roth, L.M. 1950 Humidity reaction of Tribolium J. exp. Zool., 115: 585-586.

Zhantiyev, R.D. and Durovin, N.N. 1974, The sound signal of orthoptera Zool. Zh., 53(3): 345- 358.

# APPENDIX

Appendix figs 1-16. Loss in body weight ( per cent of the initial ) of instar nymphs (I to XVI) of Gryllodes sigillatus Walker under starvation with desiccation ( 30 ± 1°C and R.H. 20 ± 5 per cent ) and starvation without desiccation ( 30 ± 1°C and R.H. 80 ± 5 per cent ).


Starvation with desiccation
Starvation without desiccation
WEIGHT (PERCENT OF THE INITIAL)
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DAYS

Fig.1

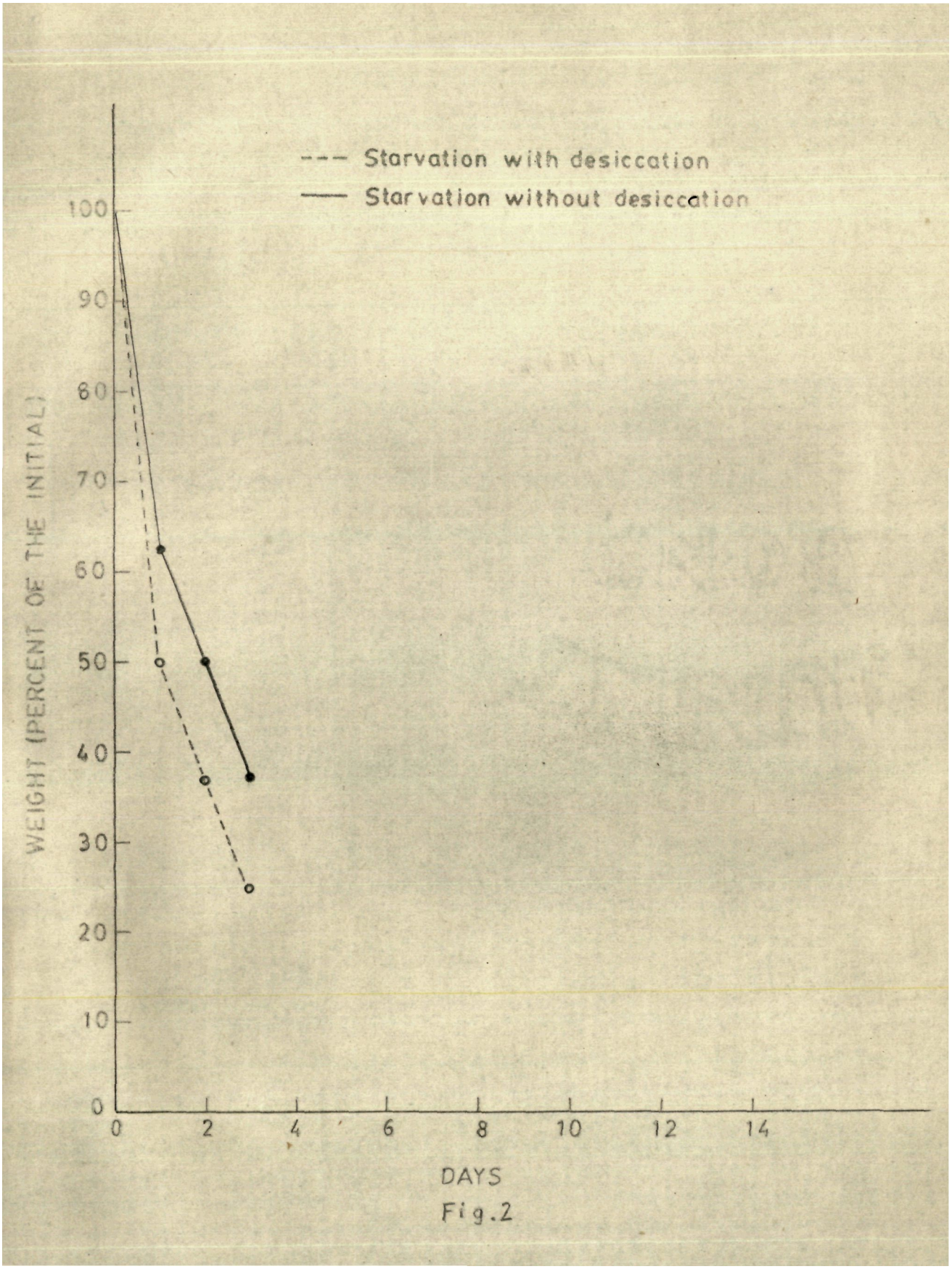
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Fig.2

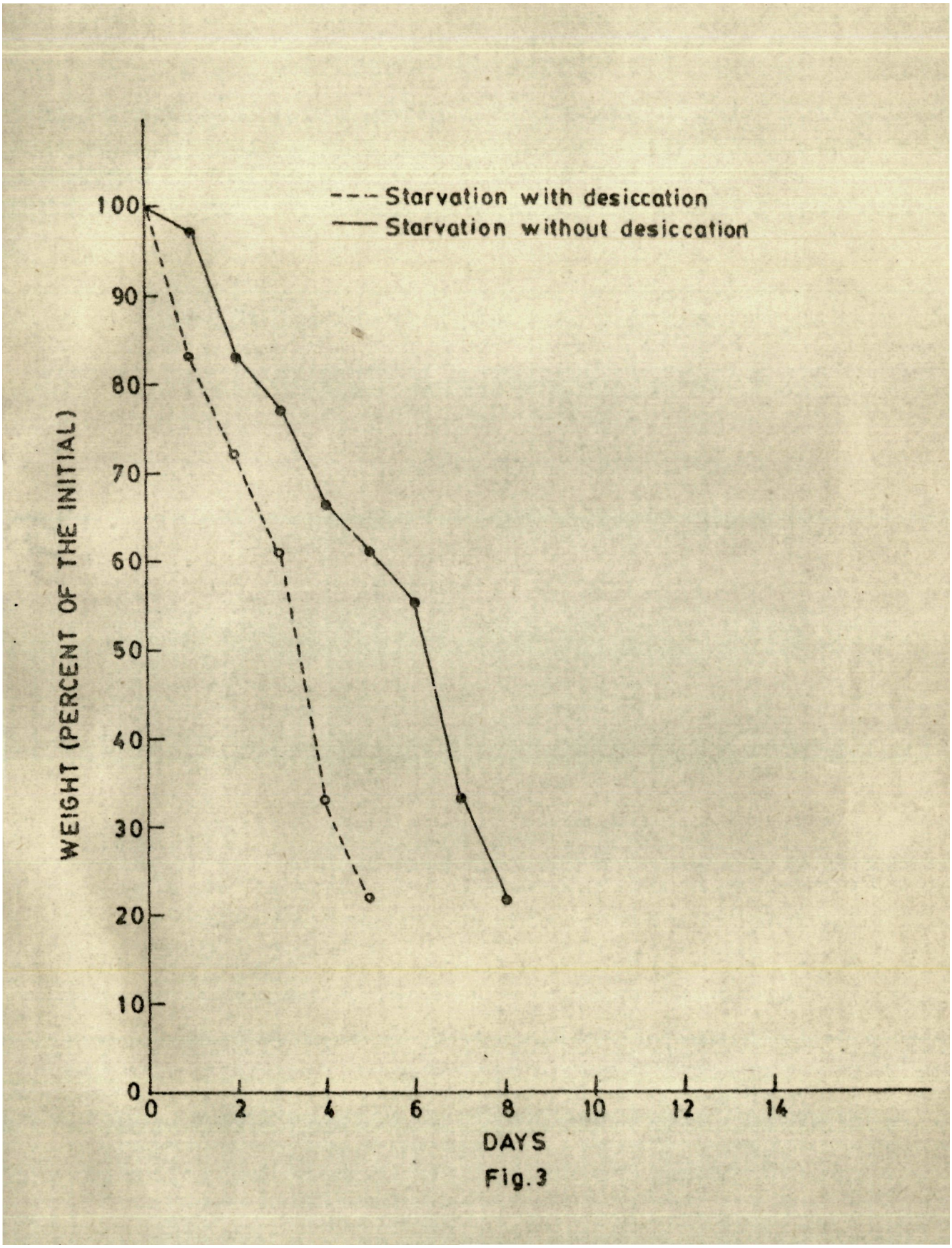
Starvation with desiccation
Starvation without desiccation
WEIGHT (PERCENT OF THE INITIAL)
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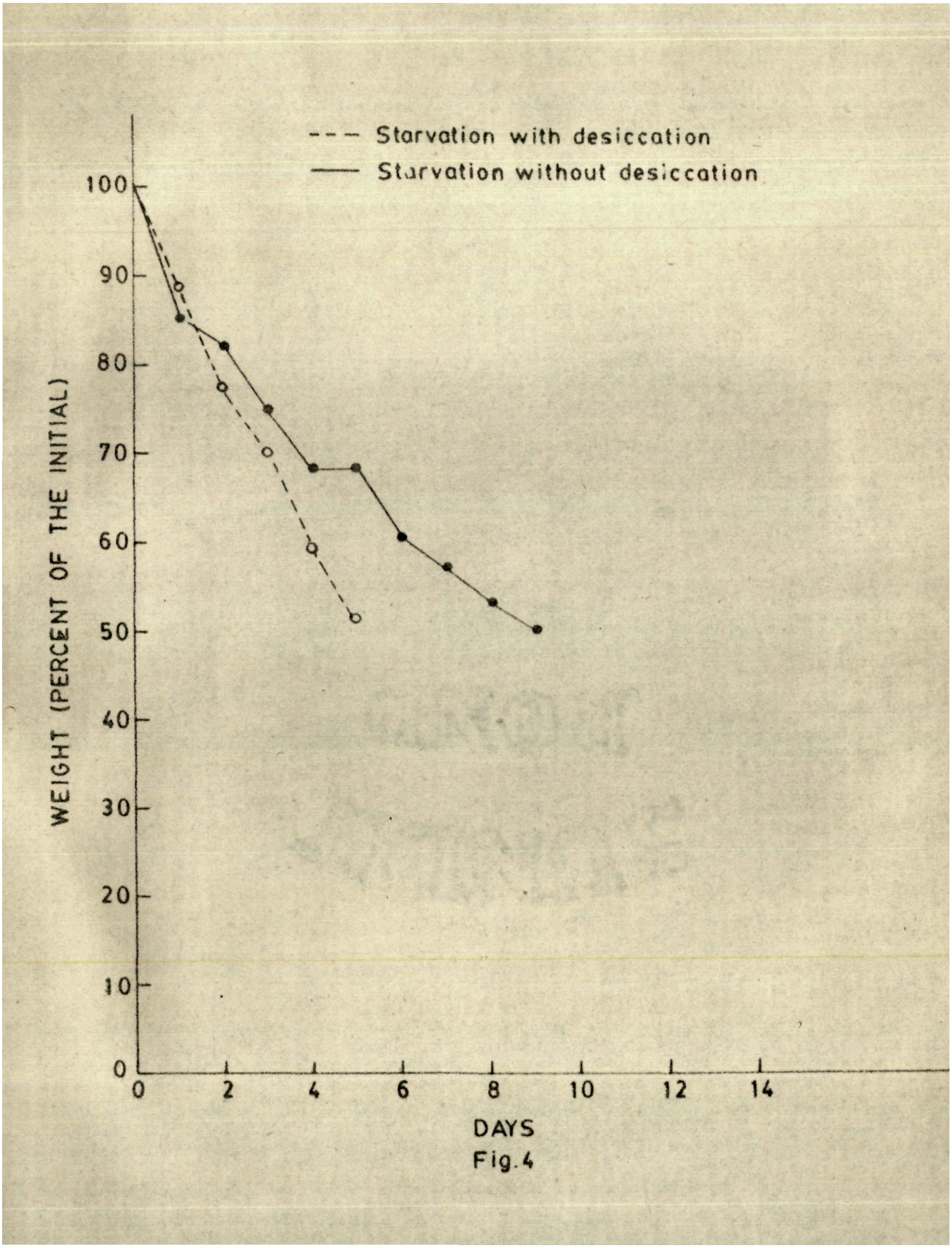
Fig.3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WEIGHT (PERCENT OF THE INITIAL)
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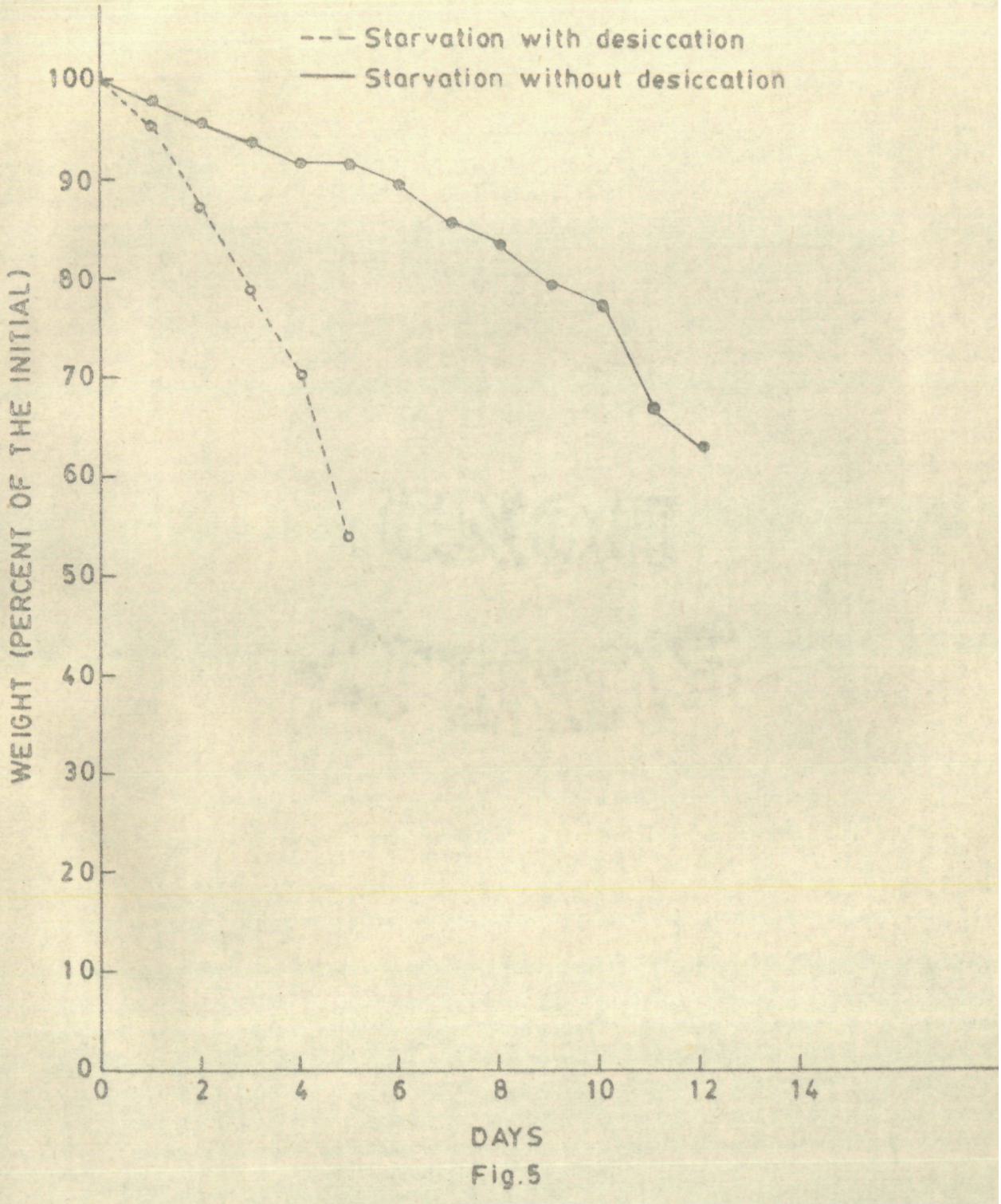
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Fig.5

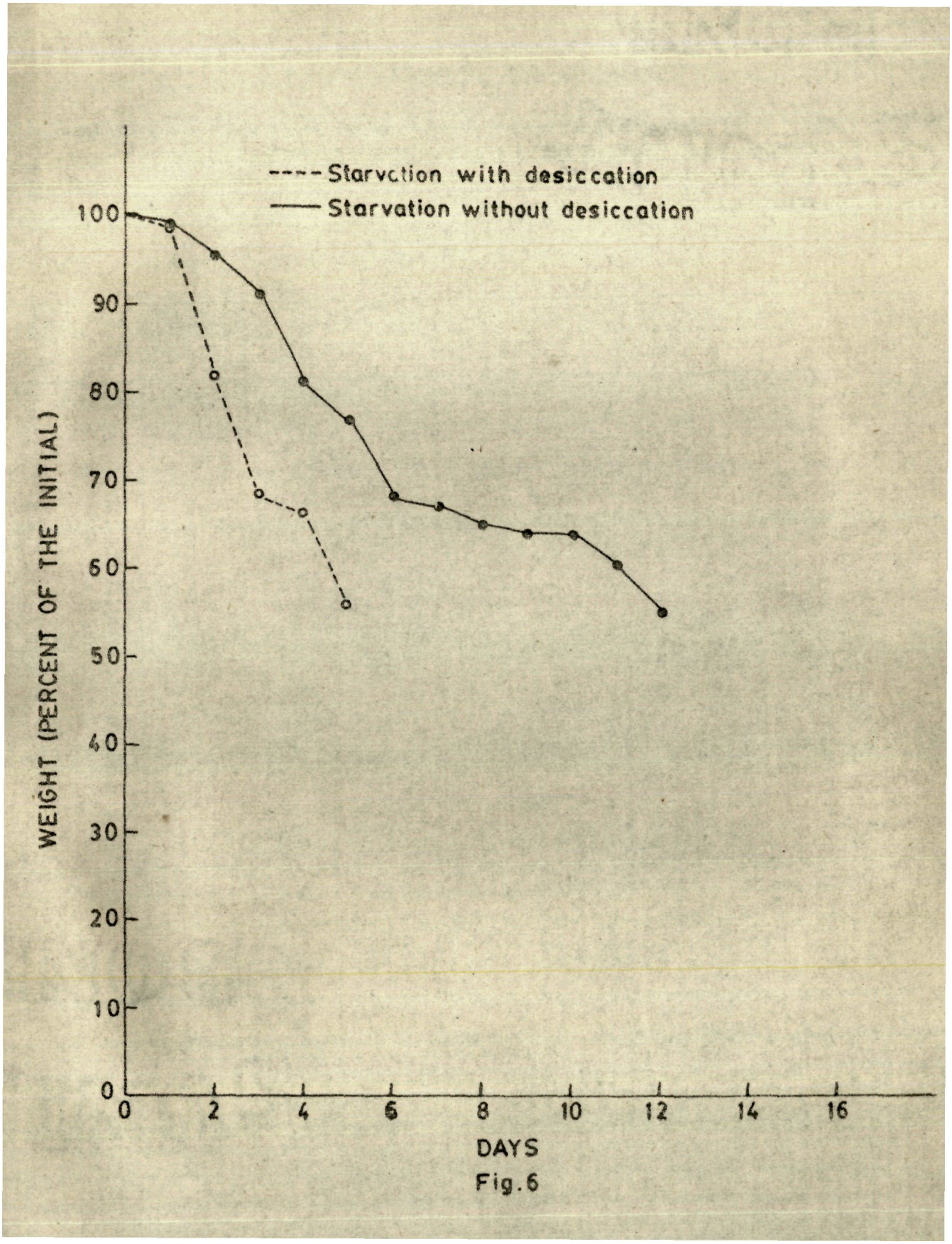
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Fig.6

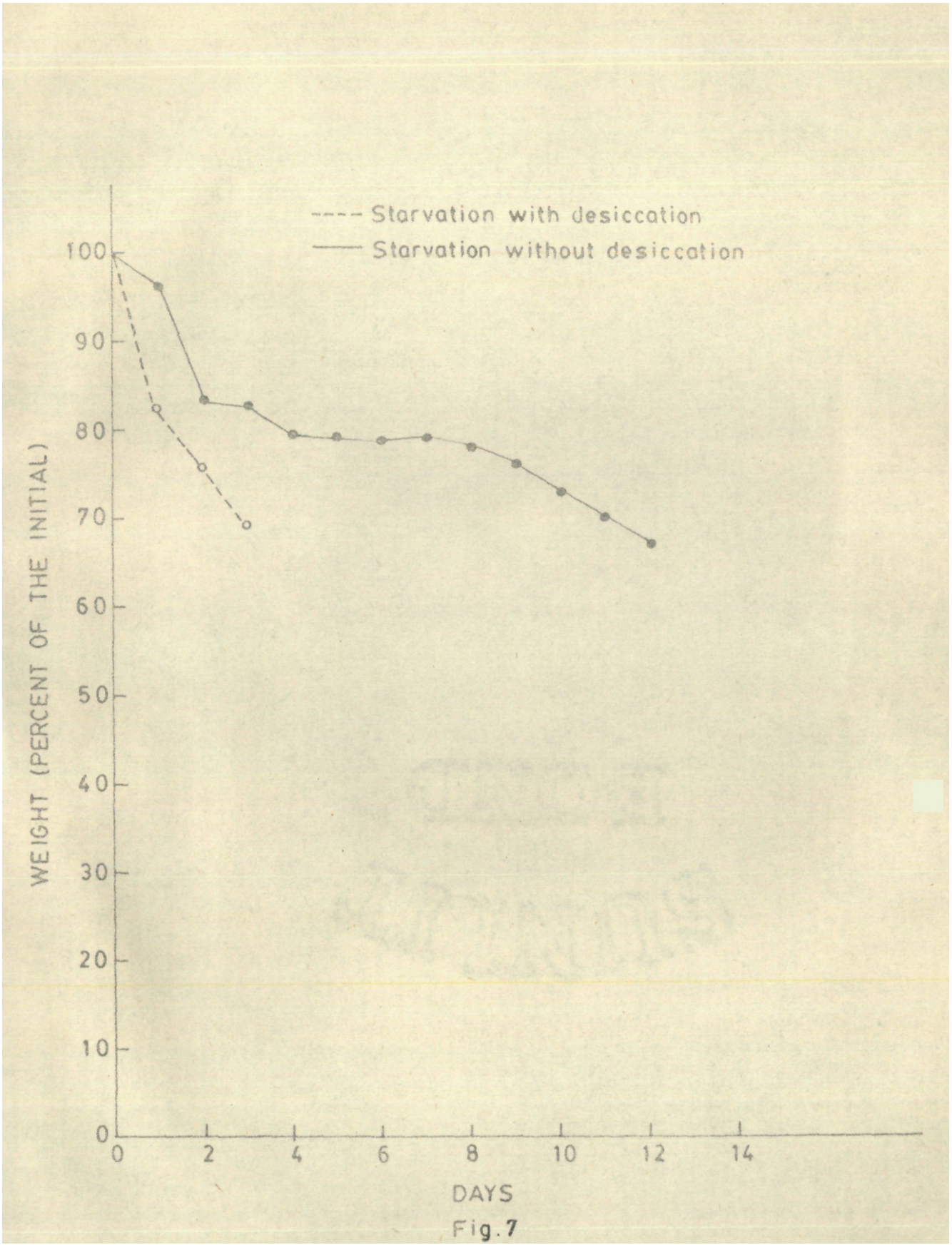
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Fig. 7

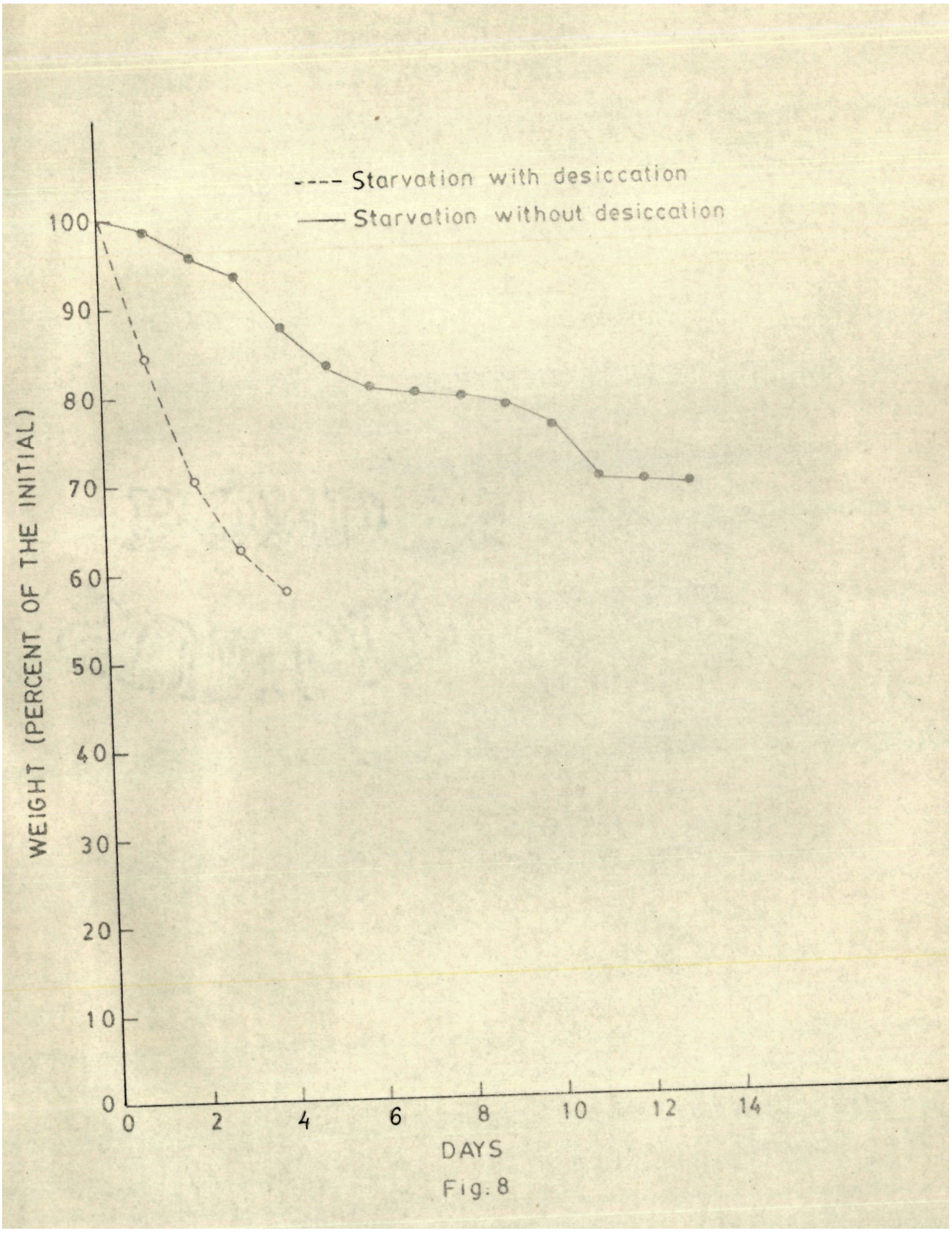
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Fig. 8

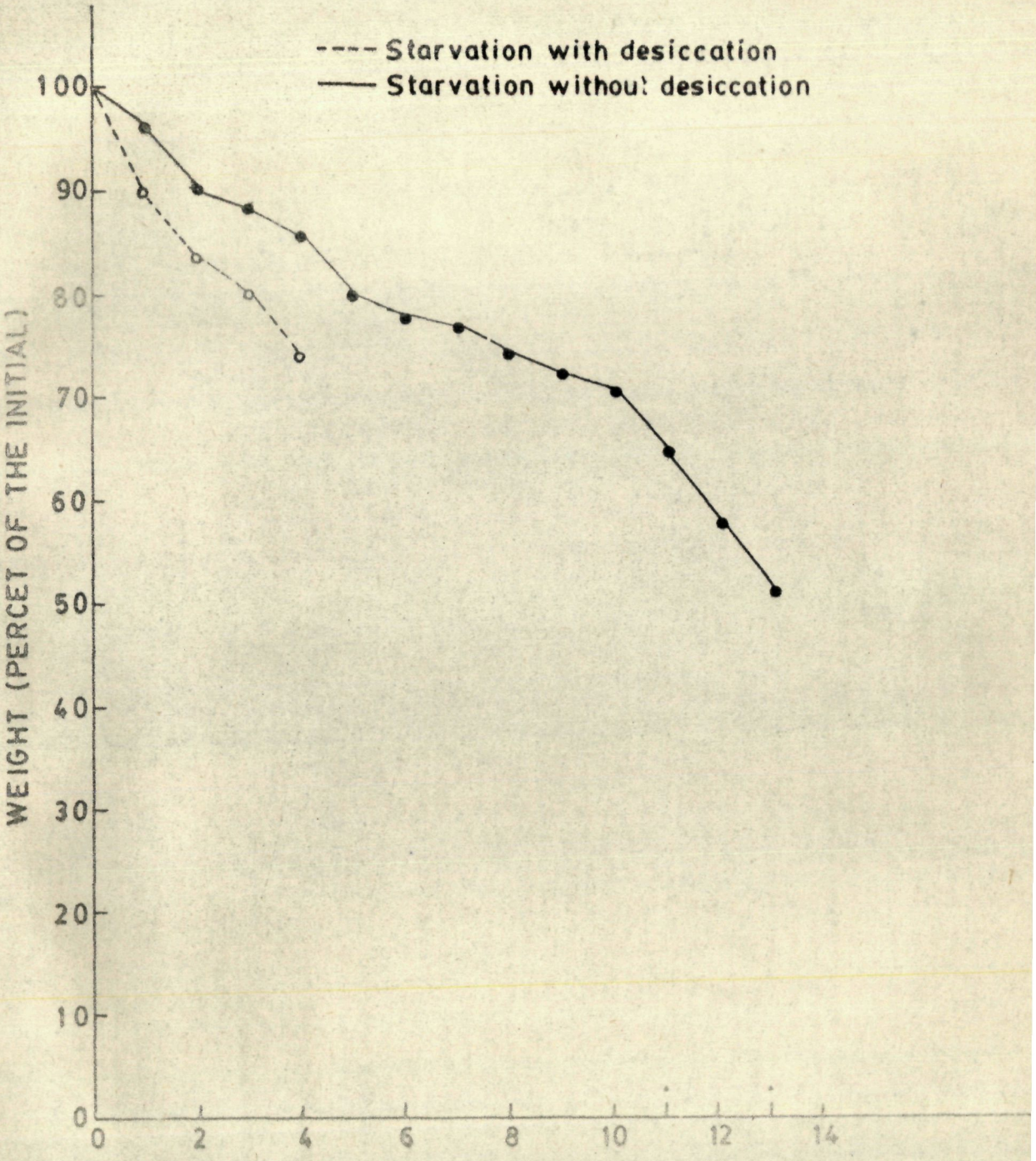
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Fig. 9

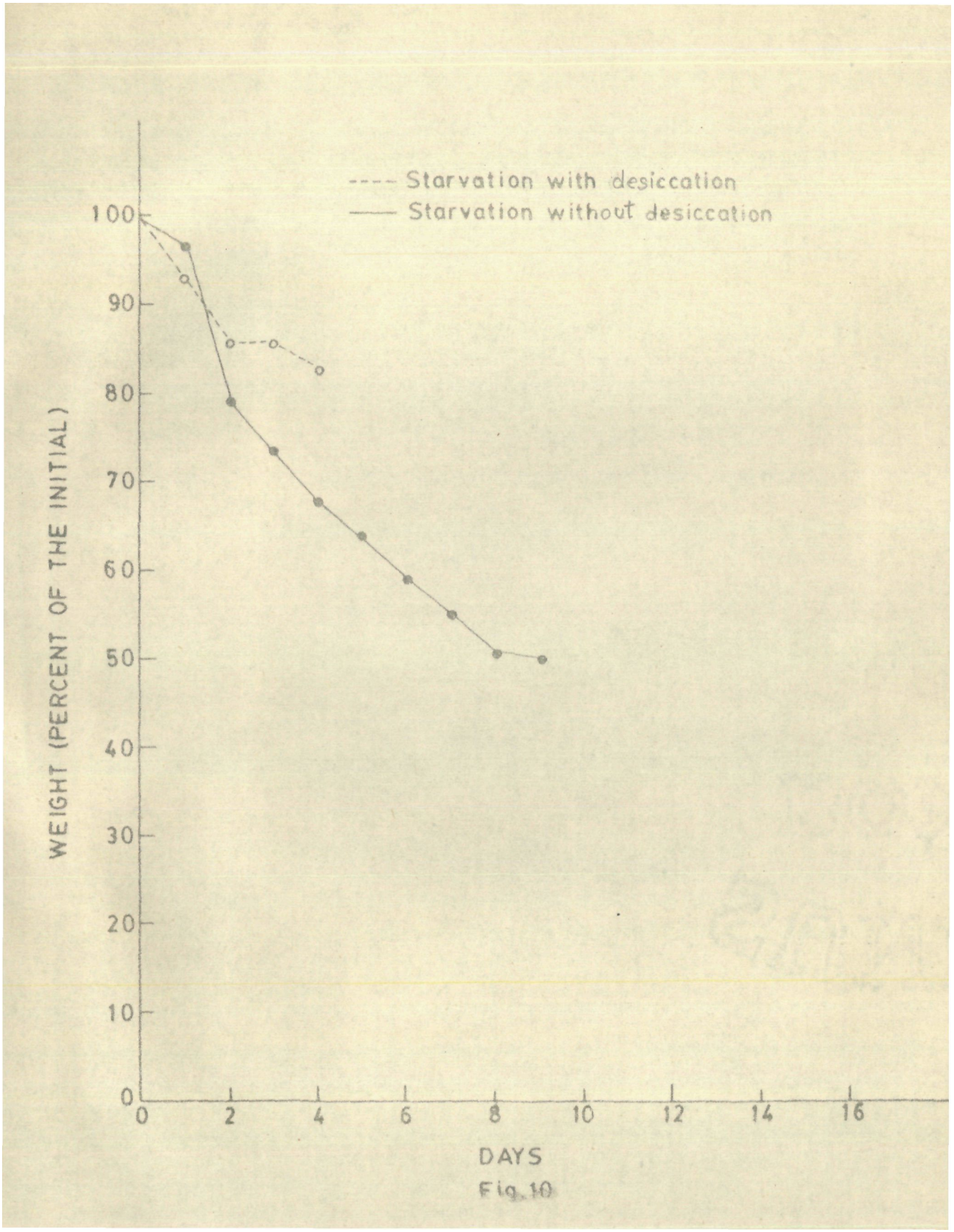
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Fig. 10

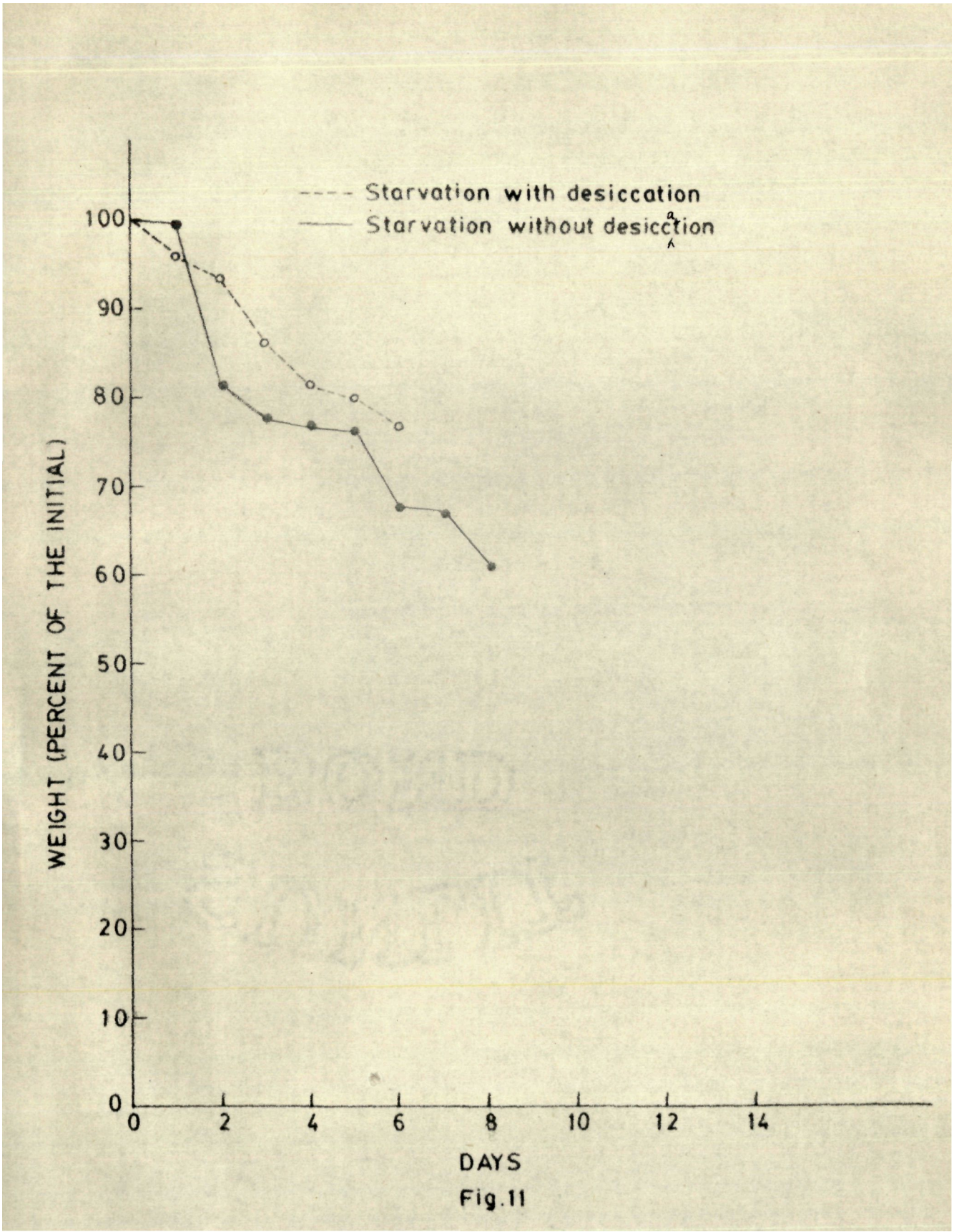
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Fig.11

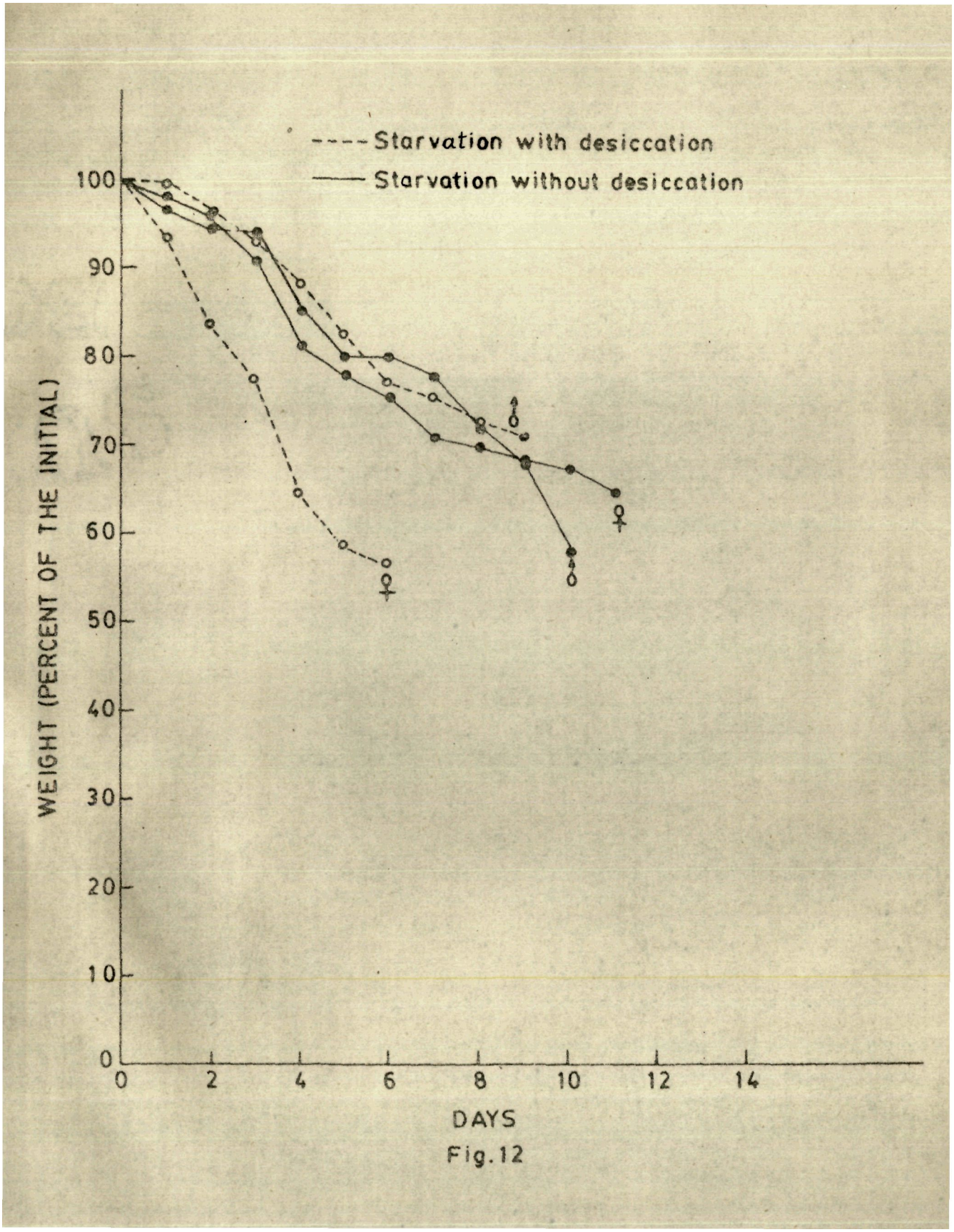
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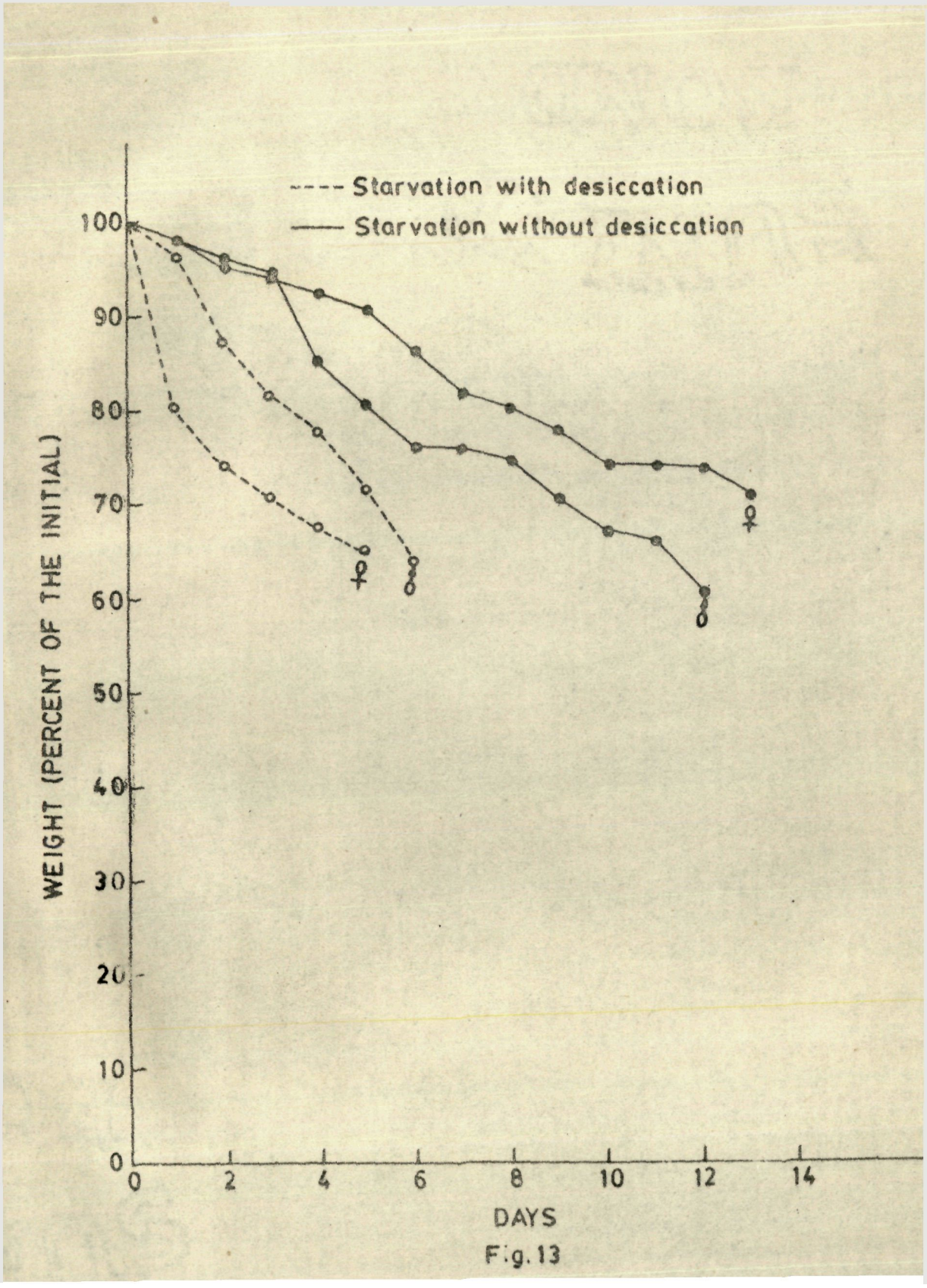
Fig. 12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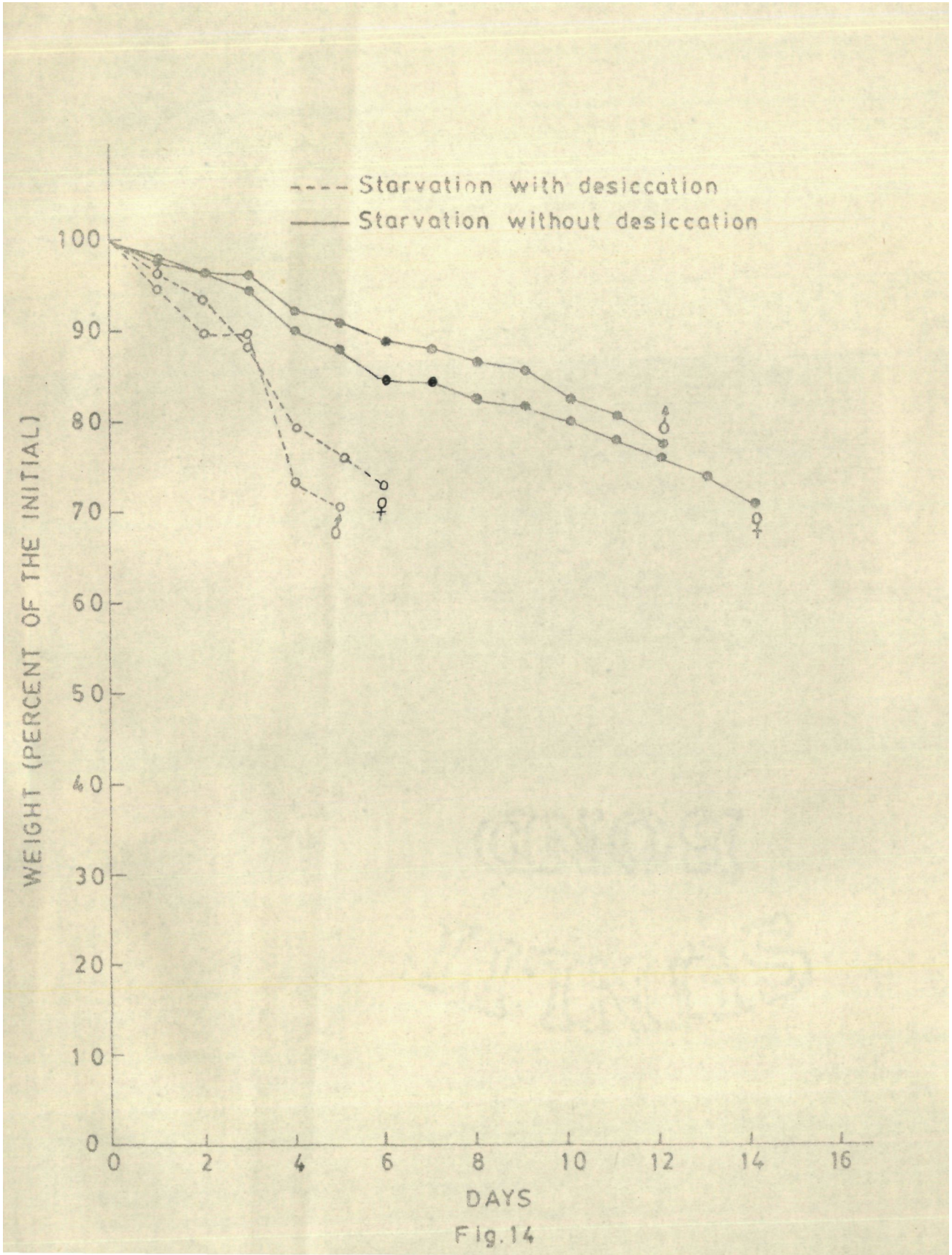
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Fig. 14

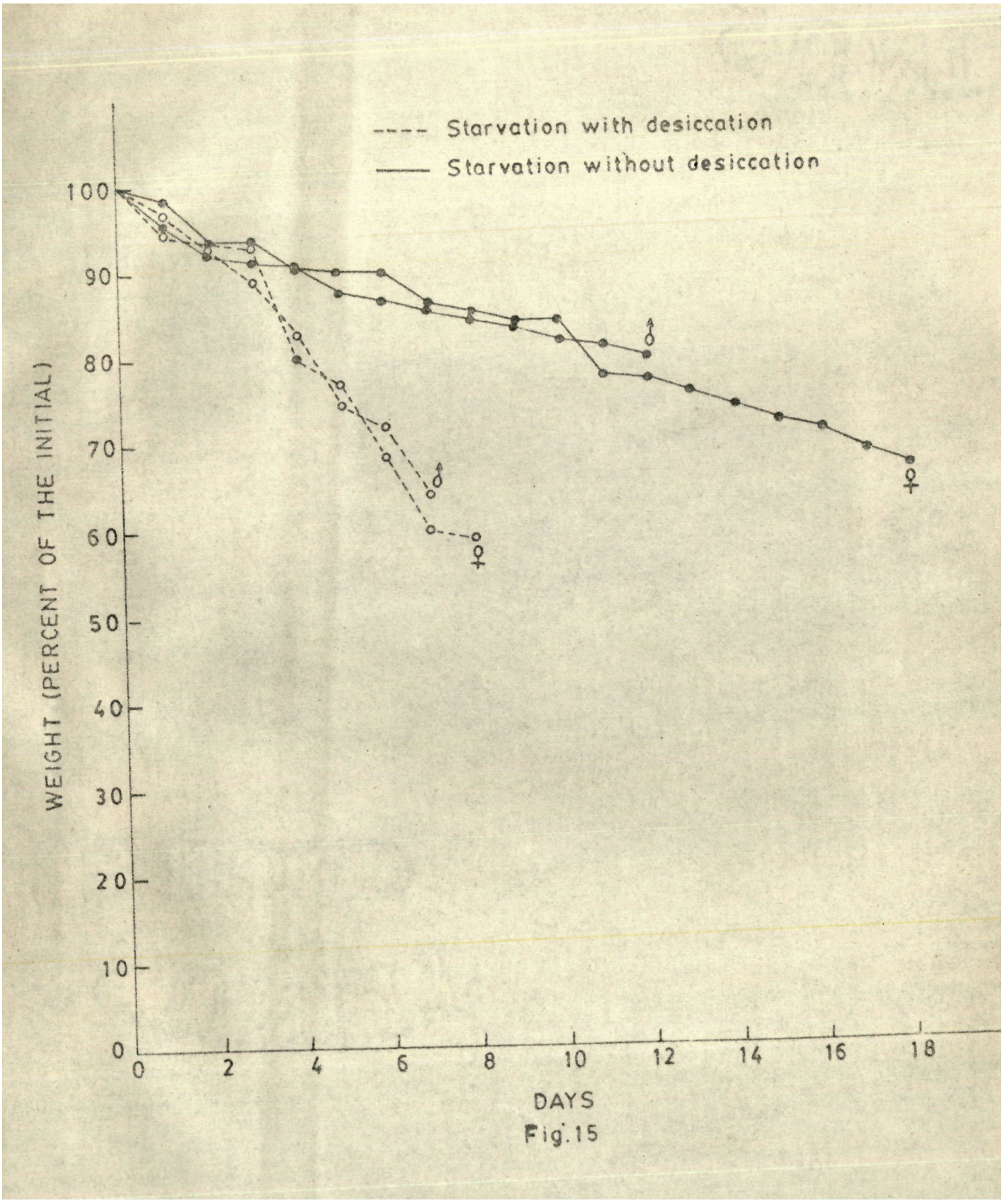
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Fig. 15

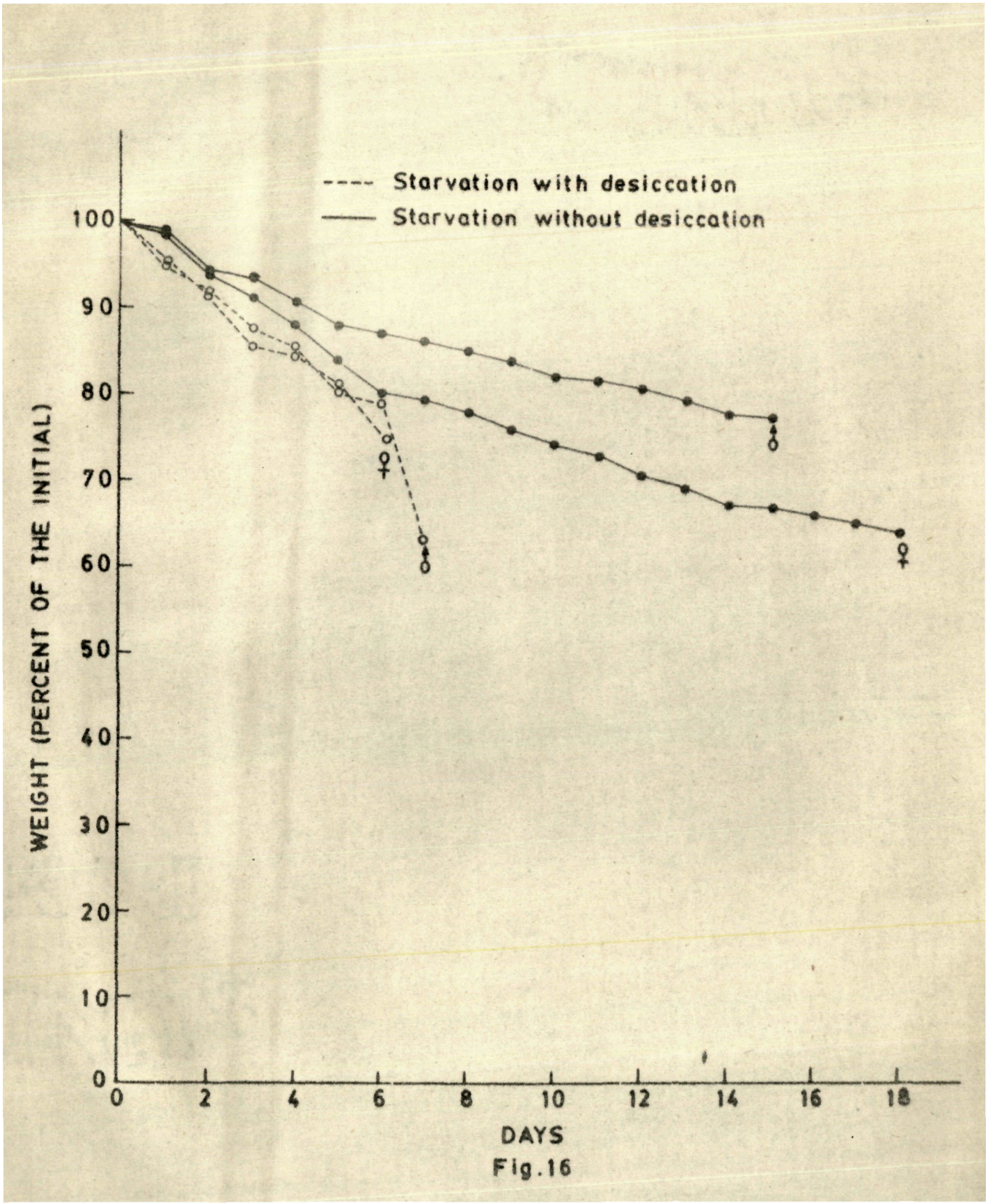
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Fig.16